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Individual Differences in Adaptation to Changes

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ABSTRACT

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Successful adaptation to changes is of great importance to today's workforce and for organizations. Built on the I-ADAPT theory (Ployhart & Bliese, 2006), this dissertation research explored the relationships among ability and personality factors, adaptability, and adaptive performance. Using a relatively simple skill acquisition task, the noun-pair lookup task, this research examined whether those relationships would be affected by the skill acquisition stages at which a change is introduced. As such, unexpected changes were introduced at different performance stages of the noun-pair lookup task. In one condition, participants experienced an unexpected change to the varied mapping (VM) version of the noun-pair lookup task at early stages of consistent mapping (CM) task learning. In the other condition, the change from the CM task to the VM task was introduced at late stages of the CM task learning. Two hundred and twenty five participants completed the noun-pair lookup task in one of two conditions. They also completed measures of two Big Five factors (openness to experience at the construct level and conscientiousness at the facet level), the I-ADAPT-M measure of adaptability, and tests of working memory capacity and perceptual speed. It was found that the timing of introducing a change did matter. Controlling for pre-change performance, participants had greater performance decrements when the change was introduced at late stages of the CM task practice than when it was introduced at early stages of the CM task practice. Ability factors and personality traits were found to be predictive of strategy choice in the

CM task. There was no evidence of the moderating effect of the performance stage at which a change was introduced on the relationship between ability factors and adaptive performance. The mediation effect of adaptability on the relationship between ability and personality factors and adaptive performance was not supported. Adaptability as measured by I-ADAPT-M was also correlated with personality traits but not with ability factors or performance on the noun-pair lookup task. In conclusion, this dissertation showed the importance of making a clear distinction between adaptability and adaptive performance, and taking into consideration skill acquisition stages in task-related adaptive performance.

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My parents' unwavering love and support has been accompanying me every step of my life, to make me strong, and to inspire me to make the most of myself. I feel truly blessed to be their child, to have them as my parents. This dissertation is also theirs.

I will always cherish the years I have spent in the Department of Psychology at Rice University.

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CHAPTER 1

INTRODUCTION

Today's workforce is faced with dynamic, ever-changing work environments (Frese, 2000; Howard, 1995; Smith, Ford, & Kozlowski, 1997). Globalization and free-market economic systems are making the business environment increasingly competitive, and at the same time, these factors are creating unfamiliar cultural, legal, and ethical demands and requirements (Conger & Benjamin, 1999). Moreover, the increased availability of information and technology has brought the Internet, computers, and software programs into every aspect of work. Technology is exerting important influences on jobs by permanently changing job tasks and requirements (Patterson, 2001; Schmitt & Chan, 1998). The implications of these changes are extensive. Employees will have to constantly update their knowledge and skills, which may include adopting a new set of skills in some cases, to keep pace (Pulakos, Arad, Donovan, & Plamondon, 2000). Whether employees can successfully adapt to changes has important consequences not only for them, but also for organizations (Ployhart & Bliese, 2006; Schmitt & Chan, 1998). When employees are not adaptive, their skills will quickly become obsolete, and they may eventually be left out of the workforce. Organizations will no doubt recognize the benefit of hiring employees who can adapt to rapidly changing environments, and they will need to consider adaptability during selection, training, and promotion.

Given its importance to both organizations and individuals for remaining competitive in the present-day business environment, adaptation to changes has been widely explored in applied and laboratory settings at the individual, team, and organization level (e.g., Chen, 2005; Lang & Bliese, 2009). In the growing literature, adaptation to changes has been labeled with a variety of terms, such as adaptability (Ployhart & Bliese, 2006), global adaptability (Schunn & Reder, 2001), and adaptive performance (Pulakos et al., 2000). Studies on adaptation to changes have evolved into two main streams: One focuses on examining environmental factors that require adaptation, and on designing and testing interventions to promote individual, team, and organization adaptation to changes (Boeker & Goodstein, 1991; Bröder & Schiffer, 2006; Marks, Zaccaro, & Mathieu, 2000; Smith et al., 1997). Examples of this approach include discovery learning and error-based training, which were suggested by Smith et al. (1997) as effective strategies to build adaptive expertise.

The other stream of research on adaptation has focused on an individual differences approach (e.g., Cronshaw & Jethmalani, 2005; LePine, Colquitt, & Erez, 2000; Ployhart & Bliese, 2006) and defines adaptation as ". . . the process by which an individual achieves some degree of fit between his or her behaviors and the new work demands created by the novel and often ill-defined problems resulting from changing and uncertain situations" (Chan, 2000, p. 4). It can be further described according to two perspectives. The first conceptualizes adaptation to changes as *adaptive performance*, an outcome variable that can be predicted by individual differences factors such as cognitive abilities and personality traits (e.g., Schunn & Render, 2001). The second has considered adaptation to change as *adaptability*, an individual difference variable in its own right comprised of a combination of knowledge, skills, abilities and other characteristics (KSAOs; e.g., Fine & Cronshaw, 1999; Ployhart & Bliese, 2006). In other words, adaptive performance and adaptability both denote a person's adaptation to changes, yet they are two different constructs, where adaptive performance is an outcome variable that can be predicted by adaptability.

This investigation was built on Ployhart and Bliese's (2006) Individual Adaptability (I-ADAPT) theory, and explored the relationships among cognitive and non-ability traits, adaptability, mediating processes and adaptive performance on a distal-proximal continuum. Adaptability was examined as a proximal determinant of adaptive performance. The relationship among the distal predictors, the proximal predictor (i.e., adaptability) and adaptive performance was investigated within the context of a skill acquisition framework (Ackerman, 1988). This framework permitted an examination of the nature of task changes as a function of the stage of skill acquisition when the changes are introduced. In sum, this study investigated adaptive performance by modeling person characteristics relevant to adaptability, relevant task characteristics, and the timing of changes in task characteristics during the learning or skill acquisition process.

The I-ADAPT Theory

In the I-ADAPT Theory (see Figure 1adapted from Ployhart & Bliese, 2006), the relations among KSAOs, adaptability, mediating process, and performance are conceptualized on a distal-proximal continuum. Distal predictors are generally traits or trait-like factors and are thought to be relatively stable. Proximal predictors are typically state-like factors and are thought to be less stable (Kanfer, 1990). In the model, KSAOs are the most distal predictors, and consist of cognitive ability, personality traits, interests, and physical ability. According to Ployhart and Bliese (2006), adaptability is a trait-like factor that affects performance in contexts where it is required. It is a representation of

KSAOs, and only KSAOs determine individual differences in adaptability. However, adaptability is hypothesized to be more proximal to performance and therefore more malleable than KSAOs, given that adaptability can be learned and changed to a degree over a period of time. Moving along the continuum in Figure 1, adaptability is proposed to be the primary and direct determinant of the mediating processes, which are more state-like and thus could be affected by environmental factors. Adaptability directly influences how individuals perceive a situation and how fast they can recognize change. It is also hypothesized that individuals with higher adaptability should be more likely to choose the appropriate strategy from the possible strategy repertoire, deal with the challenging or stressful events with an active coping style, and learn from experience (Ployhart & Bliese, 2006). As such, mediating processes such as strategy selection directly affect performance. Performance, in turn, provides feedback to the mediating processes on either maintaining or adjusting situation perception, strategy selection and so on.

By drawing the distinction between individual differences in adaptability and adaptive performance, the I-ADAPT Theory has integrated the KSAO and outcome perspectives on adaptive performance in the literature into one model. This was done through the proposed interplay between adaptability and mediating processes, and the interplay between mediating processes and performance. The following section elaborates on each components of the I-ADAPT Theory starting with the criterion of adaptive performance.

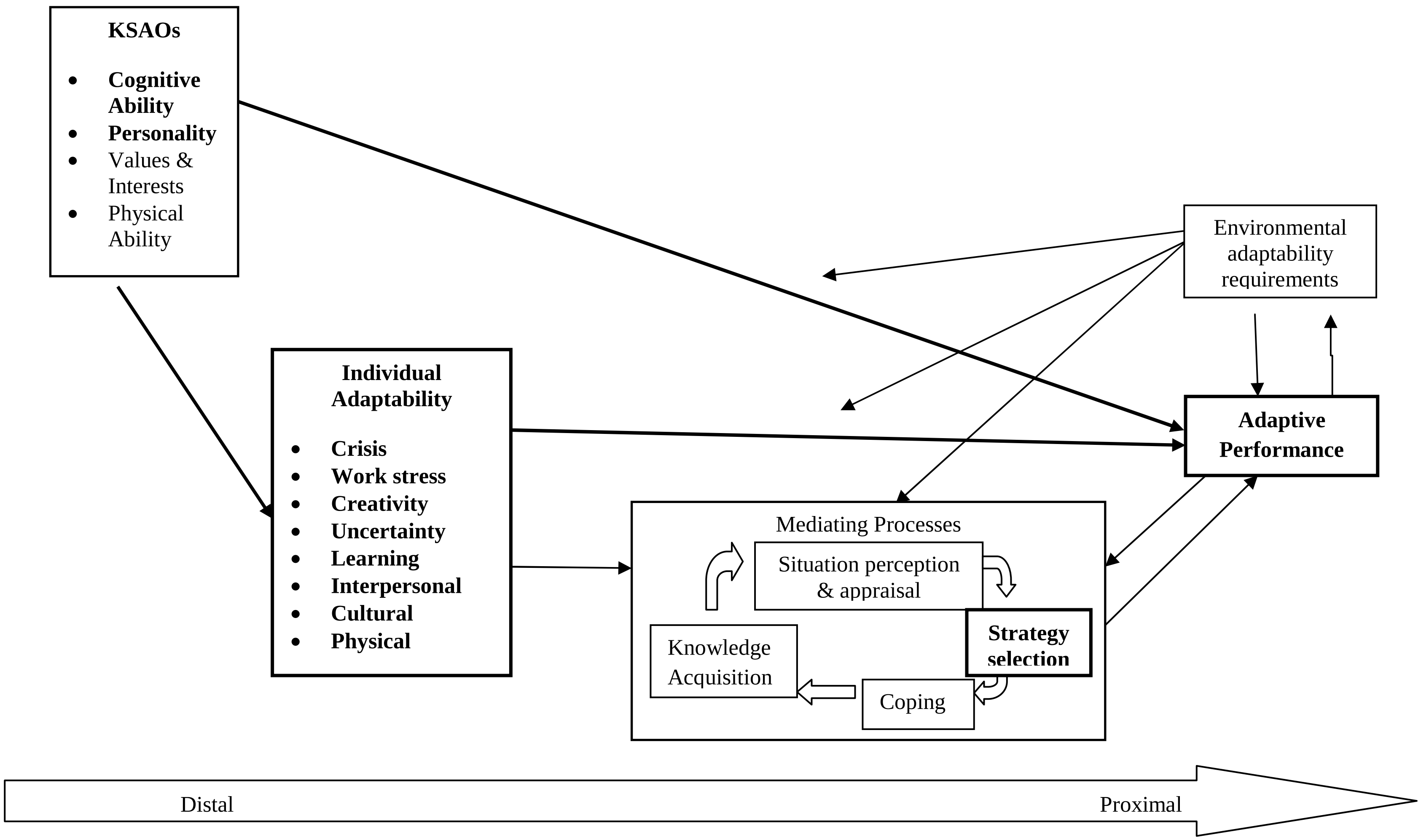


Figure 1. The simplified version of the I-ADAPT Theory. Constructs and relations examined in this dissertation are in bold.

A Review of Adaptive Performance

Adaptive performance, by definition, is an outcome variable. It is the performance in responding to changes in the environment. The body of research that examines adaptive performance can be summarized into four main streams, as suggested by Ployhart and Bliese (2006): (1) adaptive performance as coping with stressful events, (2) adaptive performance as responding to organizational change, (3) adaptive performance as strategy selection, and (4) adaptive performance as task performance. In the I-ADAPT Theory, Ployhart and Bliese (2006) incorporated the first three into the mediating processes and considered the last one, adaptive task performance, as the main dimension of the outcome of interest: adaptive performance. It is important to note that the I-ADAPT Theory does not make specific claims about the nature of adaptive performance (i.e., task performance or contextual performance, Borman & Motowidlo, 1993). In this dissertation, rather than examining the more global aspects of adaptive performance in the I-ADAPT Theory, I focused on adaptive task performance only.

In a typical study of task-related adaptive performance, participants perform a task (e.g., computerized decision making or skill acquisition task) until they reach a certain proficiency level. Then, unexpectedly, some features of the task, such as the decision rules, are changed (e.g., LePine et al., 2000). Adaptive performance is defined as how well people respond to task changes, in other words, how well they maintain their performance level on a changing task. In a broad sense, training transfer, especially far transfer (i.e., the tasks and situations in the transfer settings) concerns how individuals maintain, generalize, and adapt their trained knowledge and skills to different, and sometimes more complex, situations, (Baldwin & Ford, 1988; Chen, Thomas, & Wallace, 2005; Ford & Weissbein, 1997; Kozlowski, Brown, Salas, Smith, & Nason, 2001; Schmidt & Bjork, 1992).

Although it is generally accepted that adaptive task performance is defined as how well people respond to task changes, the operationalization of adaptive task performance differs among researchers. In a changing context, task performance cannot be measured simply as average response time and/or accuracy because the introduction of a change naturally divides performance trajectories into three stages: Pre-change period, post-change period, and the exact point when a change occurs. As such, performance on the three stages cannot be simply averaged, but should be examined in a way that takes into consideration the change and its possible effect on performance. In other words, adaptive task performance should be reflective of all possible responses to the change.

Given that there has not been a consensus on operationalizing adaptive task performance, approaches vary across studies. Some studies operationalized adaptive performance as post-change performance (e.g., Schunn & Reder, 2001), measuring performance after a change without controlling for pre-change performance. Others defined adaptive performance as post-change performance while controlling for pre-change performance (e.g., Bröder & Schiffer, 2006; LePine, 2005; LePine et al., 2000).

Lang and Bliese (2009) defined two forms of adaptability in the task-change paradigm: transition adaptation and reacquisition adaptation. According to Lang and Bliese (2009), *transition adaptation* represents the adaptability to minimize performance decrements that occur immediately in response to the change and *reacquisition adaptation* reflects how fast people pick-up the new knowledge, skills and strategies and thus how fast their performance increases after a change. To capture transition adaptation and reacquisition adaptation, Lang and Bliese (2009) suggested that discontinuous growth modeling (Singer & Willett, 2003), which is a specific type of multilevel mixed-effects model, would be most appropriate. They argued that the advantage of discontinuous growth modeling is that it is capable of capturing complex change processes and modeling transition adaptation and reacquisition adaptation while controlling for pre-change levels of both basal performance (intercept) and skill acquisition (slope). However, discontinuous growth modeling may not be the most appropriate approach for data analysis in this context. I will revisit this issue in the section on research evidence of the I-ADAPT Theory below.

Distal Predictors of Adaptive Performance

With an understanding of the criterion (i.e., adaptive performance), the next question is: What are the traits that can predict and explain adaptive performance? The I-ADAPT Theory proposes that KSAOs such as cognitive ability and personality traits are distal predictors of adaptive performance, adaptability and the mediating processes are more proximal predictors. Moving along such a distal-proximal continuum, in the following sections, I first review, from a theoretical perspective, general cognitive ability and personality traits as distal predictors of adaptive performance, followed by a discussion of adaptability and the mediating processes as proximal predictors, and finally empirical evidence regarding the relationship between these predictors and the criterion, adaptive performance.

Cognitive predictors of adaptive performance. General cognitive ability, or *g* (Spearman, 1904), has received considerable attention as an individual difference predictor of task performance, especially in complex environments (Ackerman, 1988). General cognitive ability relates to information processing capacity and efficacy (Ackerman, 1988; Kanfer & Ackerman, 1989), and "involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience" (Gottfredson, 1997, p.13). It has been demonstrated that *g* predicts not only performance during skill acquisition but that *g* is the strongest predictor of job performance and occupational level compared to other traits (Schmidt, 2002; Schmidt & Hunter, 2004). Meta-analytically derived unweighted averages for the validity of *g* across all jobs is .63 and .55 for training outcomes and job performance criterion, respectively (Schmidt & Hunter, 2004).

Given the strong predictive power of general cognitive ability across contexts, and given that tasks used to explore adaptive performance are generally cognitively involving, general cognitive ability has also been examined in terms of its relation with adaptive performance. But before going in to detail on the relation between general cognitive ability and adaptive performance, I first discuss how general cognitive ability has been assessed and its relation with other cognitive constructs, because these points are relevant to how general cognitive ability was assessed in this dissertation study.

In the conventional hierarchical abilities models, for example in Carroll's (1993) three-stratum theory, general cognitive ability is at the top, identified as the single general factor that is derived from common variance shared among the lower-order factors. The second stratum of Carroll's model includes factors such as fluid intelligence (defined as the logical thinking and reasoning process, i.e., reasoning ability, Cattell, 1943), crystallized intelligence (defined as knowledge acquired from past experience and education, such as vocabulary and comprehension), visual perception, auditory perception, and other broad content abilities. The first order of Carroll's model includes factors that are of narrower specializations and are manifestations of the second-stratum abilities. For example, inductive reasoning and deductive reasoning, which are two first-order abilities, are two representatives of the second-order ability fluid intelligence. Although Carroll's (1993) theory implies that general cognitive ability is a multidimensional construct, it has been suggested that fluid intelligence is the central factor, and is "… traditionally considered to be at or near the core of what is ordinarily meant by intelligence" (Carroll, 1993, p.196). Studies have shown that fluid intelligence explains most of the variance of general cognitive ability and accounts for performance across a variety of domains and contexts (Gustafsson, 1984; Kyllonen & Christal, 1990). Whereas fluid ability has been considered as a central construct related to *g* in the psychometric literature, working memory has also shown a close relationship with *g* from the perspective of information processing and executive attention (Kyllonen & Christal, 1990).

One of the defining characteristics of the working memory system is its emphasis on combined processing and storage. It has been shown that working memory is related to general cognitive ability, and its functions facilitate learning, reasoning, and comprehension (Baddeley, 2003). Kyllonen and Christal (1990) examined the relationship between fluid intelligence (reasoning ability) and working memory capacity and found high correlations (*r*'s from .80 to .90 in four studies) using confirmatory factor analysis. This led to the conclusion that working memory and fluid ability are largely the same construct (with the exception that fluid ability correlated more highly with general knowledge than working memory did and working memory correlated comparatively highly with processing speed). Süß, Oberauer, Wittmann, Wilhelm, and Schulze (2001) also found that working memory capacity was highly related to fluid ability, but their results showed a smaller correlation (e.g., r was less than .6) than that found by Kyllonen and Christal (1990).

The strong connection among working memory capacity, fluid intelligence and g was further confirmed by a number of studies using various tests and tasks (e.g., Ackerman, Beier, & Boyle, 2002; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999). This research has generally confirmed the idea that working memory capacity, fluid ability, and g are highly related, and that both fluid ability and working memory capacity are good indicators of g (Ackerman, Beier, & Boyle, 2005; Conway, Kane, & Engle, 2003).

Non-ability predictors of adaptive performance. Above and beyond general cognitive ability, non-ability factors such as personality traits have been shown to account for independent variance in performance (Barrick & Mount, 1991; Hurtz & Donovan, 2000; Judge, Higgins, Thoresen, & Barrick, 1999; Yeo & Neal, 2004). Existing research has suggested that personality characteristics do influence adaptive performance (e.g., LePine, 2003; LePine et al., 2000; Mumford, Baughman, Threlfall, Uhlman, & Costanza, 1993). Conscientiousness and openness to experience are two personality traits that are especially relevant in the study of adaptive performance.

Conscientiousness. A conscientious person is thought to be reliable, responsible, hard working, self-disciplined, and persevering (Costa & McCrae, 2008). Researchers have proposed that conscientiousness is a multi-faceted construct with the lower-order facets clustering around two key components: achievement/volition and dependability/responsibility (Barrick & Mount, 1991; Costa & McCrae, 2008; McCrae & John, 1992). Characteristics such as responsible, self-disciplined, thorough, and organized that are related to orderliness and cautiousness reflect dependability; characteristics such as persevering and hardworking that are related to one’s will to achieve and efficaciousness comprise the volition aspect of conscientiousness. Conscientiousness is arguably the most important personality predictor of job performance within the five factor model, which also includes agreeableness (warmth and empathy), extraversion (surgency and talkativeness), neuroticism (reversed emotional stability) and openness to experience (curiosity and intellectual orientation; Roberts, Chernyshenko, Stark, & Goldberg, 2005).With respect to whether conscientiousness predicts adaptive task performance, however, there is still much unknown. LePine et al. (2000) were among the first to examine this question. A detailed discussion on their study and findings is presented in a later section.

Openness to experience. People who score high on openness to experience are more intellectually curious, imaginative and open-minded (Costa & McCrae, 2008). In contrast to conscientiousness, there is not much empirical evidence that openness to experience generally relates to typical job performance (Barrick & Mount, 1991). However, it is reasonable to speculate that openness is related to adaptive performance because in changing environments, individuals will have to abandon the old familiar way of doing things and will have to develop an appropriate way to deal with changes. It seems likely then that openness to change and creativity would be a helpful attribute that would contribute to adaptive performance.

Proximal Predictors of Adaptive Performance

As discussed above, it is reasonable to hypothesize that there is a relationship between general cognitive ability and adaptive task performance and there is a relationship between personality traits, especially conscientiousness and openness to experience, and adaptive performance. And in the I-ADAPT Theory, as traditional stable individual differences KSAO factors, these traits are hypothesized to be distal predictors of adaptive performance. Together with other KSAO factors (see Figure 1), these traits are also proposed to be primary and direct determinants of individual differences in adaptability, which is a more proximal predictor of adaptive performance.

Adaptability. Recognized as an individual differences trait by some researchers, adaptability was defined by Fine and Cronshaw (1999) as “competencies that enable people to manage themselves in relation to the demands of conformity and/or change in particular situations” (p.39). It is thought that adaptive skills are developed through life experiences and are manifested as an individual’s values, attitudes, and behavioral styles in response to physical, social, and environmental changes. People with more developed adaptive skills are said to respond to changes better than those with less developed competencies.

In their I-ADAPT theory, Ployhart and Bliese (2006) defined adaptability as “an individual’s ability, skill, disposition, willingness, and/or motivation, to change or fit different task, social, and environmental features” (p.13). In their view, adaptability is a composite trait, a representation of knowledge, skill, ability and other characteristics (KSAOs). It is also a relatively stable individual difference characteristic. More specifically, Ployhart and Bliese proposed that adaptability has eight sub-dimensions based on taxonomy of adaptive performance developed by Pulakos et al. (2000, 2002). This taxonomy was developed using a critical incidents technique, to investigate the dimensions of adaptive performance that are required in work contexts. The eight dimensions of adaptive performance proposed by Pulakos et al. (2000) are: (a) handling emergencies or crisis situations, such as what may occur in a aircraft commander's job, (b) handling work stress, for example, when dealing with extreme heavy work load, (c) solving problems creatively, as is often required of criminal investigators, (d) dealing with uncertain and unpredictable work situations, for example, as what an executive assistant often faces, (e) learning work tasks, technologies, and procedures, which is a big component of a manager's job, (f) demonstrating interpersonal adaptability, for example, for an attorney (g) demonstrating cultural adaptability, which is important to an expatriate worker, and (h) demonstrating physical oriented adaptability, such as in extreme cold, dirty, or other challenging environments.

Based on Pulakos et al.'s (2000, 2002) work, Ployhart and Bliese (2006) suggested in their I-ADAPT Theory that overall adaptability (i.e., a higher-order factor) is a weighted composite of the eight adaptability sub-dimensions, and that each sub-dimension of adaptability is composed of various weightings of KSAOs. For example, general cognitive ability should be more strongly related to the learning adaptability sub-dimension than to physical adaptability sub-dimension.

To assess adaptability as proposed by the I-ADAPT Theory, Ployhart and Bliese (2006) developed the I-ADAPT Measure (I-ADAPT-M), comprising 55 items. Items were created to tap sub-adaptability in each of Pulakos et al.'s (2000, 2002) eight dimensions of adaptive performance. Empirical assessment of items and the scale quality have shown evidence for convergent and discriminant validity. A confirmatory factor analysis (CFA) also found support for the second-order factor structure; that is, a higher-order overall adaptability is represented by eight lower-order latent dimensions.

The Mediating Processes. In the I-ADAPT Theory, adaptability is proposed as a more proximal predictor of adaptive performance than KSAOs, and is also proposed as the primary and direct determinant of the processes mediating the relationship between KSAOs and adaptive performance. As shown in Figure 1, lying at the more proximal end, the mediating processes are state-like and dynamic, consisting of components such as coping and strategy selection. Outcomes of the mediating processes are determined by individual differences in adaptability. For example, Ployhart and Bliese (2006) expected that people with high adaptability would have a better and more accurate perception and appraisal of a situation than those with low adaptability, and then they would choose the appropriate strategy, cope with the event and learn from the experience, all of which would lead to successful adaptive performance.

Skill Acquisition Theory

Before moving to the empirical studies that are relevant to the I-ADAPT Theory, I talk about another theory that should be considered when examining adaptive task performance and its predictors: skill acquisition theory. This theory is important because, according to skill acquisition theory (e.g., Ackerman, 1988), the relationship between performance and its predictors depends on the specific stage of skill acquisition.

A typical skill acquisition process can be segmented into three phases: cognitive, associative, and autonomous (Fitts & Posner, 1967). In the literature, these three phases have been labeled with different terms, for example, Shiffrin and Schneider (1977) called them controlled processing, mixed controlled and automatic processing, and automatic processing respectively; Anderson (1982) described the declarative stage, knowledge compilation, and procedural stage. Despite the inconsistent terminology, these theories presented the same underlying process of each skill acquisition stage. And the three stages are referred as skill acquisition Phase 1, Phase 2 and Phase 3 for simplicity in the following discussion.

When first starting a skill acquisition task (i.e., a task that can be learned), there is a heavy reliance on the cognitive-attentional system. Most attention resources, if not all, are devoted to understanding the task and to formulating and testing potential strategies for task execution. Performance in this stage is characterized with slow response time and low response accuracy. With consistent practice, performance is remarkably improved, in both speed and accuracy, due to practice, which strengthens the stimulus-response connections of the skill and reduces the attentional demands of the task accordingly. Eventually, with extensive practice, tasks can be performed autonomously with minimal demands on attentional input. Performance reaches its asymptote and practice brings no further improvement.

The distinct underlying processes of the three skill acquisition stages imply that they are linked to different ability factors (Ackerman, 1988; Kanfer & Ackerman, 1989). These ability factors will be different for different tasks, but for tasks that have a speed/motor component (i.e., tasks on which most research on skill acquisition has been conducted) they will be: general cognitive ability, perceptual speed, and psychomotor ability. General cognitive ability has a strong power in explaining variance in performance in skill acquisition Phase 1 for any task. This is because the initial stages of learning will always require the focus of attentional resources. Over time, for skills that can be learned (i.e., at least part of the underlying task components are consistent – more will be said about this below) the predictive power of cognitive ability will decrease to its asymptote as performance transitions from Phase 1 to Phase 2. As such, the association between general cognitive ability and performance would not be expected to remain stable over the course of skill acquisition for skills that can be learned; instead, the association would be expected to attenuate with practice. However, for most tasks, it would be expected that the relationship between cognitive ability and task performance would not become null. Rather, because ability is a strong and consistent predictor of performance, it is expected that the ability-performance relationship attenuate and remain at an asymptotic level throughout task execution (e.g., Keil & Cortina, 2001).

The story of how cognitive ability is related to task performance in skill acquisition is more complicated than the three-phase account suggests, however. This is because the relationship between ability and task performance depends somewhat on the consistency and complexity of the task being learned (Ackerman, 1988; Henry & Hulin, 1987; Hunter & Hunter, 1984; Murphy, 1989).

Task Complexity

Task complexity is determined by the amount of cognitive demand imposed by a task (Johnson & Kanfer, 1992). Wood (1986) proposed a task complexity model in which task complexity is decomposed into three dimensions: component complexity, coordinative complexity, and dynamic complexity. *Component complexity* is determined by the number of acts required to execute the task and the number of information cues to be processed during task execution. For instance, component complexity is related to the number of displayed stimuli and the number of response choices. *Coordinative complexity* includes aspects such as the sequencing of the acts, time and frequency allowed to perform each act, and the relationship between information cues. *Dynamic complexity* refers to changes in both component complexity and coordinate complexity. Manipulation of these dimensions will change overall task complexity and affect how much attention is needed to complete a trial correctly, which, affects the relationship between cognitive ability and task performance. For example, when task complexity increases (due to increase on any the three complexity components or a combination of them), greater demands are placed on attentional resources. As such, general cognitive ability may maintain its strong predictive power throughout task execution.

Task Consistency

A task is consistent when the rules to perform the task, the task components that are to be processed, and the sequence to process those components, are invariant (Ackerman, 1987). For example, in a memory-search task, the same 10 stimuli are presented for every trial with another prime stimulus that changes from trial to trial. Participants are asked to decide whether the prime stimulus comes from the original 10 stimuli. Such a task is a consistent task because the task components (i.e., the 10 stimuli) that are to be processed are invariant. If the 10 stimuli were to differ for each trial, then the task would be an inconsistent task that could not be learned (i.e., a person would not remember the 10 stimuli because they would never be the same). In sum, the consistency of a task determines whether leaning/skill acquisition can happen, and thus affects the relationship between cognitive ability and task performance.

Task complexity and consistency are two factors that can moderate the relationship between general cognitive ability and performance in skill acquisition tasks (Ackerman, 1988). More specifically, task complexity may determine the relative dependence of performance on general cognitive ability and perceptual speed. For example, initiating appropriate performance in a very complex task places strong demands on general cognitive ability, but not on perceptual speed abilities. In a simple task, however, perceptual speed abilities may quickly take over general cognitive ability's influence on performance because Phase 1 will transfer more quickly to Phase 2 for these tasks. As to consistency, tasks that are moderately or highly inconsistent will not be easily learned because the rules will be constantly changing. For highly inconsistent tasks, people will be required to start with a new set of rules on each trial. This implies that task performance will require the focus of attentional resources throughout performance. As such, skill acquisition cannot occur and it would be expected that the relationship between general cognitive ability and task performance would not decline over the course of skill execution.

Murphy (1989) generalized the skill acquisition model (e.g., Ackerman, 1987, 1988; Anderson, 1982) to work performance and suggested the relation between general cognitive ability and overall job performance depends on job stage. He proposed that there were two stages: transition stage and maintenance stage, which mirror Phase 1 and Phase 3 in Ackerman's skill acquisition model, respectively. The transition stage marks the periods when an employee is new to a job and when an employee faces major changes in job requirements and responsibilities. In this stage, an individual needs to learn new information to perform a job or to deal with the changes in the job, both of which rely heavily on general cognitive ability. Whereas in the maintenance stage, where employees are very familiar with job procedures, general cognitive ability would no longer play a major predictive role on job performance. Instead personality and motivational factor may have a greater impact (Helmreich, Sawin, & Carsrud, 1986). .

To summarize, when examining the relationship between general cognitive ability and performance, either the performance on a skill acquisition task or on a job, both the characteristics of the task/job (i.e., complexity and consistency) and the phase/stage of performance should be considered. I use this conclusion to serve as the basis of the discussion on the relation between general cognitive ability and adaptive performance below.

Research Evidence Relevant to the I-ADAPT Theory

Given that there has not been a published report of a test of the I-ADAPT Theory in its entirety to date, there is no empirical evidence of the distal-proximal continuum, nor is there evidence of the interconnections between one component in the theory and its adjacent (e.g., the relationship between adaptability and the mediating processes). However, there are empirical studies that have examined components of the theory such as the predictive power of general cognitive ability and personality traits on adaptive task performance. This research has provided indirect but valuable information on the I-ADAPT Theory.

LePine et al. (2000) investigated how people responded to unforeseen changes in a decision making task in a naval command-and-control scenario and explored whether general cognitive ability, conscientiousness, and openness to experience could explain adaptive performance in that context. For a series of 75 trials, participants were instructed to gather information on nine aircraft characteristics, break the characteristics into rules, and make an assessment of the rules. Based on their assessment, they arrived at decisions about what actions to take and were given feedback after each decision. However, the correct combination of rules was changed unexpectedly after trials 25 and 50. Decision-making performance was calculated for the pre-change and post-change periods respectively. These researchers examined performance across three contexts (i.e., prior to any change, after the first change, and after the second change) and they found that the positive relationship between general cognitive ability and the decision-making performance in the two post-change contexts was stronger than it was in the pre-change context.

In addition to general cognitive ability, LePine et al. (2000) hypothesized that conscientiousness would be positively related to performance, and the relationship would be stronger in a post-change context than it would be in the pre-change context. They argued that to perform well on the decision-making task, individuals would need to search constantly for important information in order to decide how to appropriately weigh decision cues. Therefore, performance would largely depend on how willingly, and to what extent, individuals would exert effort toward the task. Furthermore, during the process of deciding how to weigh information cues, individuals who tend to be deliberate and orderly were thought to be more likely to evaluate the cues comprehensively and thus be more effective than those who are less deliberate and orderly. Moreover, in the post-change period, individuals typically experienced performance decrements before they realized changes were introduced in the task. Therefore, the researchers reasoned that people who had high task commitment and possessed high levels of self-competence perception (facets of conscientiousness) would maintain their performance goals and would be willing to persevere or devote even more effort to the task to figure out reasons for performance declines. People who do not possess those qualities, however, were thought to be more likely to lower their performance goals, which would result in performance declines after a change. As to openness to experience, because changing contexts require developing new and more appropriate ways of doing things, LePine et al. hypothesized that individuals who are curious and broad-minded (i.e., high on openness to experience) would do better in contexts where adaptive performance is required.

What LePine et al. (2000) found was counter to their hypotheses for conscientiousness. Although it was true that the relationship between conscientiousness and performance was stronger in the post-change context than it was in the pre-change context, the direction of the effect was reversed: Conscientiousness was negatively related to adaptive performance in post-change periods. Further analyses on the facet-level of conscientiousness revealed that the negative relation between conscientiousness and adaptive decision-making performance was driven by the dependability facet, and not the achievement facet. Stated in another way, individuals who tended to be deliberate and orderly remained committed to previously established rules in times of change rather than shifting their approach to seek out new rules. Regarding openness to experience, LePine et al. found that, although openness to experience did not explain variance in pre-change performance, those who were high on this trait made better decisions after changes were unexpectedly introduced.

In summary, LePine et al. (2000) provided evidence that general cognitive ability is positively related to adaptive performance; furthermore, they suggested that “when it came to predicting adaptability with individual differences, there was ‘much more than *g*’ ” (p. 586), given that conscientiousness and openness to experience were capable of predicting adaptive performance beyond cognitive abilities. More evidence is needed before conclusions can be drawn about the relationship between personality traits and adaptive performance and special attention should be paid to the facets of conscientiousness.

Lovett and Schunn (1999) presented a model of strategy selection called RCCL for “Represent the task, **C**onstruct a set of action strategies consistent with the task reprsentation, **C**hoose from among those strategies according to their success rates, and **L**eearn new success rates for the strategies based on experience” (p. 108) . As such, this model describes a dynamic process of strategy generation, strategy selection, and strategy modification. It predicts that individuals prefer strategies that have relatively high success rates, and that when tasks change in a way that lower the success rate of a particular strategy, individuals should be able to detect it and to select another more successful strategy.

Schunn and Reder (2001) conducted a series of three studies to further test the model, and to explore the relationship between general cognitive ability, strategy choice, and adaptive performance. They used a complex and dynamic air-traffic control task (Kanfer & Ackerman, 1989) and asked participants to land different types of planes and to avoid plane crashes under the various restrictions of weather conditions, fuel conditions, hold-level in a queue, and runway availability. By manipulating some of these restrictions (e.g., weather conditions), the optimal landing strategy was changed unexpectedly, which necessitated adjustments in participants' strategy choice.

Schunn and Reder (2001) found a similar pattern of results across studies. Specifically, participants' strategy choice in terms of runway selection was affected by the success of previous attempts on a particular runway. In other words, the observed results were in line with the prediction of the RCCL model: People adjusted their strategies based on their success rates, toward successfully solving the problem. Moreover, the results showed that people differed in their strategy choice in terms of how fast they could adapt their strategies and to what extent they could adapt right after an unforeseen change was introduced. Working memory capacity was found to be predictive of adaptive strategy choice. Schunn and Reder concluded that working memory capacity may account for variance in adaptive strategy choice. As such, when changes occur, individuals with high working memory capacity should detect them quickly and hence should adapt more quickly than those with low working memory capacity. Last but not least, their results suggested that strategy choice was positively related with participants' adaptive performance (i.e., total number of planes landed). Although Schunn and Reder (2001) did not test the mediating effect of strategy choice directly, their finding that cognitive ability was related to adaptive strategy choice, and that adaptive strategy choice was related to overall adaptive performance can be considered supportive of the general tenents of the I-ADAPT Theory.

Although studies have shown that general cognitive ability is a positive predictor of adaptive performance, there is still some disagreement about the importance of ability for predicting performance in a changing context. In fact, a recent study by Lang and Bliese (2009) has suggested that general cognitive ability is negatively related to adaptive performance. Lang and Bliese (2009) used a tank battle task in which participants controlled their tank to fire missiles and shoot computer-controlled adversarial tanks while avoiding being hit. After half of the 600 performance trails, the scenario environment unexpectedly changed in several aspects, which made the task more complex and difficult. For example, the number of enemies increased from one to three and there were often multiple missiles from the opponents fired simultaneously. These changes may not have been initially apparent to participants. Lang and Bliese (2009) examined how this unforeseen change affected performance in the context of both transition adaptation (i.e., performance decrements right after a change) and reacquisition adaptation (i.e., learning rate in the postchange period controlling for prechange learning rate). Through a complex analysis that included discontinuous growth modeling, Lang and Bliese (2009) reported that transition adaptation (i.e., performance decrements right after a change controlling for pre-change performance and learning rate) was negatively related to general cognitive ability, and there was no evidence for a relationship between reacquisition adaptation and general cognitive ability.

In contrast to others' findings, Lang and Bliese's (2009) results seem counterintuitive. I think there are at least two potential problems in their study that may account for the results and are worth discussing. First, as most of the studies on adaptive task performance, Lang and Bliese's (2009) did not consider skill acquisition stages when introducing changes. Thus they did not know participants' performance level at the point where the change was introduced. That is, in a task that enables skill acquisition (i.e., a task that has some consistently mapped components such as the air-traffic control task use by Kanfer & Ackerman, 1989), during later stages of skill acquisition, high- and low-ability people will typically differ in their level of performance. Higher ability people will acquire skills faster and thus will reach higher levels of performance more quickly than lower ability people. As such, in the context of Lang and Bliese's study, people with higher ability would have acquired more skill before the change was introduced (i.e., they may have automated some routines), and therefore, they would have more of that skill to lose when changes were introduced. So a reasonable question to ask is if the change were introduced after 100 trials rather than 300 trials, would Lang and Bliese have had the same findings? What if the change were introduced after 500 trials? In other words, Lang and Bliese (2009) did not consider that the relationship between adaptive performance and general cognitive performance may depend on the complexity and consistency of the particular task that is used, and may also depend on the stage at which a change is introduced.

Second, the discontinuous growth model that Lang and Bliese (2009) used to capture transition adaptation, reacquisition adaptation, and their relationship with general mental ability was not an appropriate method in this context. Discontinuous growth models are multilevel mixed-effects models that can capture complex transitions using multiple time variables and individual differences. Each person's performance across blocks over time comprises the Level 1 analysis. Individual differences such as general cognitive ability and personality are the Level 2 predictors. In the Level 1 model, timevarying predictors that specify when each person experiences the hypothesized shifts can be included, for example, by coding all measurement occasions before an unforeseen change into 0, and all measurement occasions after that change into 1.

However, discontinuous growth models are not applicable to the data in Lang and Bliese's (2009) study. As mentioned in the brief description of the tank task, after the unforeseen change, the task became more complex and therefore more difficult. As such, the score a participant received (i.e., performance criterion) after a change was not comparable to the score obtained before the change. More specifically, a lower post-change score did not necessarily indicate a performance decrement, given that the post-change score was obtained on a more difficult task than the pre-change scores. In other words, although the pre-change and post-change scores were both calculated on the same point system, the points themselves were no longer commensurate because the task was essentially different (i.e., more difficult) after the change. Therefore the scores cannot be entered together into the Level 1 analysis of the discontinuous growth model and as such the discontinuous growth model was not an appropriate method to use to analyze such a dataset.

CHAPTER 2

THE CURRENT STUDY

As has been reviewed, there are mixed findings on the relationship between cognitive ability and adaptive performance. This relationship may be better understood by taking into consideration the skill acquisition process embedded in a particular task. With regard to personality traits, conscientiousness and openness to experience are two personality traits that are of particular interests in the area of adaptive performance (e.g., LePine et al., 2000).

Inspired by these ideas, this dissertation further explored the effects of cognitive and non-cognitive factors on adaptive performance based on the I-ADAPT Theory. Unlike previous research (e.g., Lang & Bliese, 2009; LePine et al, 2000), this dissertation used a simple task (the noun-pair lookup task) whose characteristics have been well explored (e.g., Ackerman & Woltz, 1994). Although it is a simple task, the advantage of using it is that its performance levels are understood, which made it possible to tease apart potential confounding factors (e.g., performance level) that may affect the relationship between adaptive performance and its predictors.

Noun-Pair Lookup Task

The noun-pair lookup task is a promising task for studying adaptive performance because it is a relatively simple task that has been studied extensively in the skill acquisition literature (e.g., Hertzog, Cooper & Fisk, 1996; Hertzog, Touron, & Hines, 2007; Touron & Hertzog, 2004a, 2004b; Touron, Swaim, & Hertzog, 2007). It is a type of substitution task that involves both perceptual speed process and associative learning processes (Ackerman & Woltz, 1994). An illustration of the noun-pair lookup task is shown in Figure 2 (adapted from Ackerman & Woltz, 1994). In this task, nine word pairs are presented in columns across the top of a computer screen (e.g., “artist” and “desk” form a word-pair) and a probe word-pair is presented in the center of the screen. The participants’ task is to decide whether the probe word-pair matches any of the nine pairs at the top of the screen by pressing a response key indicating yes or no. One important feature of the noun-pair lookup task in this study is that it has two versions: In one version, the word-pairs presented at the top remain the same for all trials (i.e., it is a consistent mapping task; CM; Ackerman, 1987; Shiffrin & Schneider, 1977). For example, in Figure 2, “artist” would be paired with “desk” across all trials in practice, although their placement across the nine columns would change after each block. In the varied mapping task (VM; Ackerman, 1987; Shiffrin & Schneider, 1977), although the words in each row stay the same throughout all trials, the pairings would change from one trial to the next. Placement of the words across columns would also change in the VM task. For example, “artist” would be paired with “desk” in one trial, but it may be paired with “lamp” in the next trial.

artist	**farmer**	**clerk**	**lawyer**	**doctor**	**plumber**	**nurse**	**dentist**	**teacher**
desk	**rug**	**bed**	**table**	**lamp**	**chair**	**stool**	**couch**	**dresser**

DOES THE PAIR BELOW MATCH ONE OF THE PAIRS ABOVE?

teacher dresser ?

Press “T” for YES Press “2” for NO

Figure 2. Illustration of the noun-pair lookup task.

Between the CM and the VM versions, the noun-pair lookup task only varies on its consistency but not on complexity. The CM and the VM tasks are of the same complexity level, because the numbers of the stimuli to be processed (i.e., 18 words and 9 noun-pairs) in each trial are the same in the CM and the VM tasks (component complexity; Wood, 1986). However, the CM task is a consistent task because the noun-pairs stay the same for all trials. In contrast, the VM task is an inconsistent task because the pairings among the 18 words change on each trial. The consistent nature of the CM task makes both a scanning strategy and a retrieval strategy possible. A scanning strategy refers to scanning the word-pairs at the top of the screen to decide whether there is a match between the displayed pairs and the probe word-pair. A retrieval strategy involves memorizing all pairs at the top of display, and then comparing the probe word-pair with those stored in memory. Obviously, when the word-pairs are memorized correctly, the retrieval strategy is superior to the scanning strategy (i.e., it is more efficient) because scanning and searching are not necessary for producing an answer (Ackerman & Woltz, 1994). As such, the CM version of the task does not really require learning, but it can be learned and the different phases of skill acquisition should be apparent when people chose to learn the word pairs. For the VM version of the task, the only way to obtain a correct response is to use a scanning strategy because the word pairs at the top of the screen constantly change, and thus they cannot be learned.

Ackerman and Woltz (1994) asked participants to perform both the VM and CM versions of the noun-pair lookup task over an extended period of time, from which they depicted performance trajectories for both versions of the task and investigated how cognitive abilities (i.e., reasoning ability and perceptual speed) are related to performance. Several important findings were reported. First, initial performance for the VM and the CM trials had similar RT means but over extensive practice, RT in the CM condition was dramatically reduced from 2500 ms to 1000 ms and remained at around 1000 ms, suggesting that learning did occur in the CM version of the task (see Figure 3; adapted from Ackerman & Woltz, 1994). There was less reduction in RT in the VM condition. Second, reasoning ability correlated with both CM and VM task performance, but the correlation was stronger in the CM condition than it was in the VM condition, presumably due to the memory demands of the CM task over practice. Third, the correlations between perceptual speed and initial task performance were high in both the CM and VM versions and were of similar magnitude, given that the initial performance in both tasks relied on scanning speed and accuracy. However, the correlation between perceptual speed and performance attenuated over practice in the CM task, but showed little change in the VM task. This suggests that when word pairs were gradually learned and memorized in the CM task, performance became less dependent on perceptual speed for scanning, but more on reasoning ability for memorizing and retrieval. Fourth, in the CM condition, participants who used the scanning strategy throughout task execution had lower reasoning ability scores than those who used the memory retrieval strategy. In addition, as shown in Figure 3, both scanners and retrievers reached the automatic phase of performance (reflected by the asymptotic nature of the skill acquisition curves) after extensive practice; retrievers' RT decreased to below 1000 milliseconds, but scanners' RT did not.

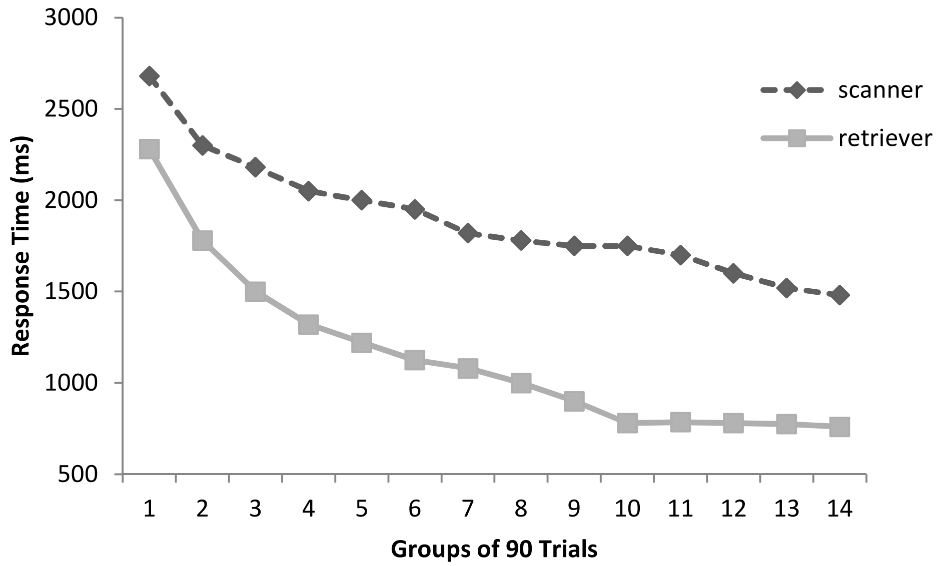


Figure 3. Consistent mapping (CM) response time means for scanners and retrievers, adapted from Ackerman and Woltz (1994).

The noun-pair lookup task lends itself to the study of strategy selection because the CM version of the task enables strategy choice, but the VM version does not. As such, participants' strategy shifts during practice in the CM task and strategy choice in the CM task given prior exposure to the VM task can be examined. Rogers and Gilbert (1997) observed that extensive VM practice (1080 trials on two days) made older adults more likely to adopt a retrieval strategy in a subsequent CM task than if the older adults had started with the CM task directly. No such effects were found for younger adults. This suggests that exposure and practice with the VM task may help older people familiarize themselves with the task and may make them more likely to adopt the retrieval strategy when starting the CM task after the VM task. Their findings inspire further investigation of whether practice influences strategy choice in this dissertation.

Research Questions

This dissertation addresses the following research questions: (1) Whether the relations between adaptive performance and ability and non-ability traits are affected by the skill acquisition phase at which a change is introduced; (2) Whether individual differences in adaptive strategy choice can be explained by ability and non-ability traits; (3) Whether strategy choice in the CM task are affected by prior practice in the VM task. Change in this study was defined as shifts between the task versions: from the VM task to the CM task, and from the CM task back to the VM task. Given the nature of this task, the shifts between the CM task and the VM task do cause changes to task complexity, but rather they result in changes in task consistency.

To properly address the above research questions, this study used a between-subjects design. The two between-subjects factors were the performance stage at which a change was introduced and the other was the effect of VM practice on the following CM performance. The change of most interest was from the CM task to the VM task. Because skill acquisition occurs only in the CM task, a focus on this change allowed the examination of the effect of the skill acquisition phase at which a change is introduced. In one condition, the change was introduced at the early processing stage of the CM task (i.e., the early stage of skill acquisition), where performance starts to improve (i.e., deceased RT). In the other condition, the change was introduced at a later processing stage of the CM task (i.e., later stage in skill acquisition), when performance plateaus. Regarding the effect of VM practice, in the condition where the change was introduced at an early stage of CM performance, participants were also exposed to the VM task at the beginning of the experiments. In the condition where the change was introduced later during skill acquisition, participants started with the CM task directly. For ease of description, from this section forward, one condition will be called the early-change condition, and the other condition will be called the late-change condition.

As to the second research question, strategy choice with the noun-pair lookup task is usually examined via RT given that a scanning strategy cannot improve performance measured by RT as much as a retrieval strategy can. As such, the faster a participant's RT on the CM task, the more likely she or he has been using a retrieval strategy. Details on the categorization of strategy choice are presented in the Results section. In addition to using RT to identify strategy use, a recall test and a self-report strategy use assessment were administered at the end of the noun-pair lookup task. The self report was assumed to provide extra information on participants' strategy choice. With regard to the recall test, it was assumed that the more participants could recall from the CM noun-pairs, the more likely it would be that they used a retrieval strategy during CM practice.

Regarding the cognitive ability and non-ability factors, working-memory capacity and perceptual speed were used as predictors of performance on the noun-pair lookup task. Previous studies (e.g. Ackerman & Woltz, 1994) showed that reasoning ability and perceptual speed were valid predictors of performance on this noun-pair task. In this dissertation, working memory capacity instead of reasoning ability was measured. Working memory capacity is a valid index of general cognitive ability, and it is related to reasoning ability to a considerable degree, although they are not the same construct (e.g., Ackerman et al., 2005; Conway et al., 2002). Moreover, working memory capacity has been shown to be associated with substitution tasks like the noun-pair lookup task (e.g., Harris, Wagner, & Cullum, 2007).

For non-cognitive predictors, given conscientiousness and openness to experience are the two Big-Five personality factors that are theoretically related, and have been empirically linked to adaptability and adaptive performance, they were also examined in this dissertation. In addition, according to Ployhart and Bliese (2006), trait adaptability is more proximal than KSAOs in predicting and explaining adaptive performance. As such, individual differences in adaptability were also assessed using the I-ADAPT-Measure.

Adaptive performance in this study was operationalized as post-change performance on the VM task, controlling for the pre-change performance on the CM task.

Hypotheses

Individuals with higher working memory capacity are more likely to adopt a retrieval strategy in the CM task than their counterparts with lower working memory capacity and thus their performance (i.e., RT) will start to improve at an early stage of the CM task practice. Because those higher in working memory capacity would be learning the noun pairs earlier, they may experience more performance decrements than those with lower working memory capacity when a change is introduced early. Furthermore, it is predicted that after extensive practice, individuals with low and high working memory capacity will both reach asymptomatic performance in the CM task. When a change to the VM task is introduced at later stages of skill acquisition (i.e., the late-change condition), people with higher working memory capacity may experience greater performance decrements than their lower ability counterparts, however the difference in their performance decrements will be smaller than it would be when the change is introduced at an early stage.

Hypothesis 1: The relationship between working memory capacity and post-change performance is moderated by the performance level at which a change is introduced. That is, the relationship should be stronger when a change from the CM task to the VM task is introduced at the stage where performance is still improving (i.e., early in skill acquisition) than when it is introduced at the stage where performance shows little improvement (i.e., at later stages of skill acquisition).

With respect to the two non-cognitive predictors, it is hypothesized that openness to experience will be positively related to using a retrieval strategy, and that the dependability facet of conscientiousness will be negatively related to a retrieval strategy. People high on openness are more likely to try new things, so they may be more likely to choose a new retrieval strategy in the CM task, even though a scanning strategy leads to satisfactory performance. People high on the dependability facet of conscientiousness keep things organized and in order, so they are more likely to remain committed to a good, though not perfect, scanning strategy.

Hypothesis 2: People who are high on openness will choose a retrieval strategy more quickly in the CM task. Openness to experience should predict strategy choice above and beyond working memory capacity and perceptual speed.

Hypothesis 3: People who are low on the dependability facet of conscientiousness will adopt a retrieval strategy more quickly in the CM task. Dependability should predict strategy choice above and beyond working memory capacity and perceptual speed.

Note that Hypotheses 1 to 3 test the direct effects of distal predictors on adaptive performance. Given that adaptability measured by the I-ADAPT-M is assumed to be a more proximal predictor of adaptive performance than KSAOs, it is hypothesized that:

Hypothesis 4: Adaptability will be positively related to working memory capacity, perceptual speed, conscientiousness and openness to experience.

Hypothesis 5: Adaptability will mediate the relationship between the distal ability and non-ability traits (working memory capacity, perceptual speed, conscientiousness, and openness to experience) and adaptive performance.

Prior research suggests (Rogers & Gilbert, 1997) that practice on the VM task helps people familiarize themselves with the task. This dissertation study further explored this issue by employing a two-condition design. The early-change condition started with the VM task and then changed to the CM task; the late-change condition started with the CM task directly. To compare strategy choice in the CM task in these two conditions, I hypothesize that:

Hypothesis 6: People who start with the VM task will be likely to switch to a retrieval strategy earlier in the CM task than people who start with the CM task.

CHAPTER 3

METHOD

Participants

Two hundred and twenty-five undergraduate students were recruited with flyers and through the Psychology Experiment Subject Pool. They received either 2-hour experiment credits or $20 for their participation.

Measures

Cognitive ability. Perceptual speed ability was assessed by Finding A's test and Identical Pictures test (Ekstrom, French, & Harman, 1976). Working memory capacity was measured by automated Operation Span task (Unsworth, Heitz, Schrock, & Engle, 2006). Description and sample items of the three tasks are provided in Table 1.

Non-cognitive traits. Conscientiousness was measured using facet level scales from International Personality Item Pool (IPIP; Goldberg, 1999). The scale consists of 60 items, 10 items per facet. The six facets are: self-efficacy, orderliness, dutifulness, achievement striving, self-discipline and cautiousness. An example item for self-efficacy is "I complete tasks successfully", "I like to tidy up" is an example item from the orderliness facet, the dutifulness facet consists of items such as "I try to follow the rules", for the achievement striving, an example item is "I go straight for the goal", "I get chores done right away" is an example item for the self-discipline facet and the cautiousness facet is assessed by items such as "I choose my words with care." Openness to experience was measured at its construct level, with 10 items such as "I enjoy hearing new ideas" and "I am not interested in abstract ideas." Participants were instructed to rate how accurately these statements describe them as they generally are on a 5-point Likert scale from “1 = very inaccurate” to “5 = very accurate.”

Adaptability was measured using the I-ADAPT-M (Ployhart & Bliese, 2006) which consists of 55 items on eight sub-dimensions: crisis-oriented adaptability, cultural-oriented adaptability, work stress-oriented adaptability, interpersonal-oriented adaptability, learning-oriented adaptability, physical-oriented adaptability, uncertainty-oriented adaptability, and creatively-oriented adaptability. Examples include, “I enjoy learning new approaches for conducting work” and “I become frustrated when things are unpredictable.” Participants were instructed to rate the extent to which they agree with each statement on a 5-point Likert scale from “1 = strongly disagree” to “5 = strongly agree.”

Table 1. Ability measures.

Measures	Descriptions & Examples
Perceptual Speed Tasks	
Finding A's Test (Ekstrom, French, & Harman, 1976)	How fast participants are in finding the letter "a" in words. Individuals are presented with five columns of words on each page and are asked to put a line through words that contain letter A. There are two parts and participants have 2 minutes for each part.
Identical Pictures test (Ekstrom, French, & Harman, 1976)	How fast one can match a given object. The target object is shown at the left of a row, with five test objects presented to its right. Participants are asked to pick the one test object that matches the target object at the left.
Working Memory Tasks	
Operation Span Task (Unsworth, Heitz, Schrock, & Engle, 2006)	Participants verify mathematical operations (make true/false judgments) and memorize words, for example, "(5 * 2) – 2 = 8?; DOG". The operations alternate with the presentation of the words and the participants have to report all the words in the correct serial order at the end of the series.

Noun-pair lookup task. The same noun-pair lookup task as used in Ackerman and Woltz (1994) was used with new word pairs. The noun-pairs in the VM task and the CM task were from the category norms of Batting and Montague (1969) and were randomly grouped into three sets of nine pairs (see the Appendix). For the consistent mapping (CM) version, the word pairs stayed constant throughout practice; however, the orders of the word pairs were randomized at the beginning of each block of trials. For the varied mapping (VM) version, new word pairs were established on each trial. As in

Ackerman and Woltz (1994) and other studies using the noun-pair lookup task (e.g., Touron, Swaim, & Hertzog, 2007), for both the consistent mapping and varied mapping versions, half of the trials were positive (match).

Self-report strategy. Participants were asked the question "what were the strategies you used to do this noun-pair task?" and to type their answers.

Recall test. The eighteen noun pairs used in the CM tasks were tested in a recall task administered on the computer. The words presented in the top row in the noun-pair task were presented as prime words randomly, one at a time, and participants were asked to recall their corresponding pair and type their answers.

Procedure

There were three parts to the study. First, participants completed the paper and pencil perceptual speed test, computer-administered personality measures via MediaLab Research Software (Empirisoft Corporation, New York, NY) and computer-administered working memory capacity task through E-Prime software (Psychological Software Tools, Pittsburgh, PA) in that order. After a 5-minute break, the noun-pair lookup task started. In the early-change condition (see Figure 4 as an illustration of the sequence of the noun-pair lookup task), participants began with the VM task for 10 blocks (18 trials per block), and then the task was changed to the CM task for 20 blocks. The second unforeseen change to the varied mapping version was then introduced. After a brief period (10 blocks), the task was again changed back to the CM task. The CM task continued for 45 blocks. In the late-change condition, participants started with the CM task directly for 60 blocks, continued on 20 blocks of the VM task and completed 5 blocks of the CM task at the end. The numbers of blocks of the CM practice before the unexpected change to the VM task in the two conditions were decided based on previous studies (e.g., Ackerman & Woltz, 1994) and a pilot study. More specifically, it was expected that in the early-change condition, after 20 blocks of practice on the CM task, participants would still be in the learning stage of the word pairs. In the late-change condition, after 60 blocks of the CM task, it was expected that performance would reach its asymptotic level. The total number of blocks was the same for the two conditions.

The early-change condition:

VM_1 (10 blocks) --- CMs1 (20 blocks) --- VM_2 (10 blocks) --- CMs2 (45 blocks)

The late-change condition:

CMs1 (60 blocks) --- VM_2 (10 blocks) --- VM_1 (10 blocks) --- CMs2 (5 blocks)

Figure 4. Sequence of the noun-pair lookup task in the early-change condition and the late-change condition. The noun-pairs in VM1 and VM2 were different from each other but the same sets of VM noun-pairs were used in the two conditions. The CM noun-pairs were the same within the task and across conditions. CMs1 and CMs2 were CM task session 1 and CM task session 2.

For each noun-pair task trial, the display of word pairs was presented for up to 7 s during which participants responded (responses longer than 7 s were be coded as errors). Upon response, the display was cleared and the next trial began. Participants were instructed to respond as fast as possible while maintaining 90% accuracy. Feedback regarding their mean RT and accuracy was be provided after every 18 trials (i.e., after each block). The frequency of feedback, the duration of the display of word pairs (7s) and the performance criterion in the instruction (90%) were decided based on previous studies (e.g., Ackerman & Woltz, 1994). At the conclusion of the noun-pair lookup task, participants completed the self-report strategy use, the recall test, and were debriefed.

CHAPTER 4

RESULTS

The analyses are presented in two parts. First, I will review the preliminary results on predictors and criteria respectively. Second, the major analyses conducted to test the main hypotheses are reviewed.

Missing Data and Outlier Analyses

Prior to statistical analyses, data were examined for abnormalities and missing data. For the perceptual speed tests, two participants were late for the study and missed both the Finding A's test and the Identical Pictures test and five participants missed the Finding A's test. For the noun-pair lookup task, four participants did not complete it due to computer operating errors. Regarding outliers, five participants were excluded from further analyses due to their extreme values (i.e., 3 standard deviations above or below the mean) on predictor variables. For the noun-pair lookup task, fifteen participants were further excluded due to either their chance-level accuracy or they were identified as multivariate outliers. In sum, data of 201 participants were analyzed to test the hypotheses with 103 participants in the early-change condition and 98 participants in the late-change condition.

Analyses on Predictor Variables

Table 2 displays descriptive statistics (means, standard deviations, and reliability estimates) for the predictor variables, overall and by condition. The reliabilities of the facet-level conscientiousness and the construct-level openness to experience were similar to those reported in the IPIP (Goldberg, 1999).

Table 2. Number of items, reliability estimates, means, and standard deviations for the predictor variables, overall and by condition.

	# Items	r_{xx}	Overall *M*	Overall *SD*	early-change *M*	early-change *SD*	late-change *M*	late-change *SD*
Perceptual Speed								
Finding A's	100	.83[a]	30.60	7.68	30.10	8.03	31.17	7.31
Identical Pictures	48	.91[a]	39.99	6.60	40.09	6.64	39.89	6.56
Working Memory Capacity								
Operation Span	75	.75	50.01	15.14	50.45	14.46	49.57	15.84
Conscientiousness								
Self-efficacy	10	.77	3.93	.84	3.94	.85	3.93	.83
Orderliness	10	.88	3.44	1.17	3.36	1.16	3.52	1.17
Dutifulness	10	.66	4.08	.86	4.09	.88	4.07	.91
Achievements-striving	10	.81	4.00	.90	4.02	.90	3.99	.89
Self-discipline	10	.88	3.01	1.12	2.97	1.09	3.05	1.16
Cautiousness	10	.82	3.24	1.11	3.26	1.08	3.22	1.14
Openness to Experience	10	.76	3.92	1.07	3.88	1.08	3.95	1.06
Adaptability								
Crisis	6	.85	3.72	.90	3.77	.86	3.66	.93
Cultural	5	.77	4.32	.75	4.30	.76	4.35	.74
Work stress	5	.80	3.06	1.20	3.03	1.21	3.08	1.19
Interpersonal	7	.79	4.19	.74	4.20	.72	4.18	.77
Learning	9	.85	3.81	.78	3.87	.77	3.74	.79
Physical	9	.69	3.41	1.07	3.43	1.08	3.40	1.06
Creativity	5	.77	3.63	.89	3.71	.85	3.54	.92
Uncertainty	9	.78	3.38	.89	3.36	.88	3.39	.89

Note. Overall N = 222 except for the Finding A's test (N = 215). The early-change condition, N =111 except for the Finding A's test (N = 108), the late-change condition, N = 111 except for the Finding A's test (N = 107). [a] Test- retest reliability. Reliability estimate for Operation Span was reported by Unsworth et al. (2006). For all the other measures, reliability estimate was Cronbach's α.

Participants were randomly assigned to a condition and therefore no differences on the predictor variables were anticipated. As shown in Table 2 and confirmed by independent sample *t*-test, no differences were found between the two conditions with regard to perceptual speed, working memory capacity, facet-level conscientiousness, openness to experience, or facet-level adaptability.

Table 3 presents the intercorrelations of all predictor variables. Of note in the table is the correlation between the two perceptual speed tests, Finding A's test and Identical Pictures test, which was significant but of small magnitude. This may be due to the fact that Finding A's and Identical Pictures tap different perceptual speed factors: PS-Scanning and PS-Pattern Recognition, respectively (Ackerman & Cianciolo, 2000; Ackerman & Kanfer, 1993). Although the correlation is small, the means and standard deviations of the two tests and the correlation are in line with the findings for the same tests reported in Colom, Rebollo, Palacios, Juan-Espinosa, and Kyllonen (2004).

Table 3 also shows a null relationship between operation span and the two perceptual speed tests, which was not too surprising. As mentioned above, Ackerman and colleagues (Ackerman & Cianciolo, 2000; Ackerman & Kanfer, 1993) pointed out that there are multiple speed factors. In additional to PS-Pattern Recognition and PS-Scanning there are PS-Memory and PS-Complex, which make substantial demands on working memory. PS-Pattern Recognition and PS-Scanning tests are relatively easy and may not tax working memory. Ackerman, Beier, and Boyle (2002) found similar results between computation span (a variation of the operation span) and Finding a and t test (a variation of the Finding A's test). These tests were chosen because they each account for independent variance in the criterion in the broader sense. That is, I was not concerned with their lack of colinearity but was most concerned with their correlation with criteria, which will be discussed below.

With regard to the I-ADAPT-M, the eight sub-adaptabilities were significantly correlated with one another and most of them also correlated with conscientiousness facets and openness to experience. However, only two sub-adaptability facets were significantly correlated with ability factors: perceptual speed (measured by Identical Pictures) was negatively correlated with cultural adaptability, and working memory capacity was positively correlated with creativity-oriented adaptability. This suggests that adaptability is a representation of ability, skills, personality, and other characteristics as posited by Ployhart and Bliese (2006).

Table 3. Intercorrelations of predictor variables.

Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	
1. Finding A's test	1.00																	
2. Identical Pictures	.23	1.00																
3. Operation Span	.06	.06	1.00															
4. Self-efficacy	.00	.05	.08	1.00														
5. Orderliness	.09	.08	-.04	.26	1.00													
6. Dutifulness	.00	.04	-.03	.45	.34	1.00												
7. Achievement-striving	.06	.04	.06	.50	.38	.43	1.00											
8. Self-discipline	.06	.03	-.06	.57	.55	.45	.66	1.00										
9. Cautiousness	.07	-.01	-.03	.45	.39	.53	.30	.45	1.00									
10. Openness to experience	-.08	-.10	.17	.22	-.17	.05	.14	.06	-.04	1.00								
11. Crisis	-.04	.07	.03	.43	.05	.16	.28	.21	.09	.13	1.00							
12. Cultural	-.08	-.14	.11	.20	.04	.22	.30	.21	-.04	.46	.12	1.00						
13. Work Stress	.05	.12	.11	.41	-.06	.23	.17	.23	.11	.00	.40	.02	1.00					
14. Interpersonal	-.09	-.04	.11	.42	.06	.24	.23	.22	.01	.39	.19	.61	.08	1.00				
15. Learning	-.04	.09	.09	.50	.21	.27	.57	.51	.17	.22	.28	.36	.24	.35	1.00			
16. Physical	.00	.06	.06	.32	-.05	.16	.29	.23	-.04	-.02	.30	.23	.47	.22	.37	1.00		
17. Uncertainty	-.03	-.02	.07	.43	-.28	.08	.18	.18	-.12	.27	.46	.25	.52	.2700.33		.48	1.00	
18. Creativity	-.10	.03	.15	.38	-.01	.07	.37	.28	-.05	.39	.34	.32	.23	.37	.64	.35	.44	1.00

Note. Correlations greater than .13 are significant at .05 level, correlations greater than .17 are significant at .01 level. Overall *N* = 222 except for the Finding A's test (*N* = 215). Perceptual speed was measured by variable 1 and 2, working memory capacity was measured by variable 3, facets of conscientiousness were measure by variable 4 to variable 9, facets of adaptability were measured by variable 11 to 18.

The Noun-Pair Lookup Task

Data on the noun-pair lookup task were analyzed by condition. Median RTs for correct trials are generally used to analyze performance at the block level on the noun-pair lookup task (e.g., Ackerman & Woltz, 1994; Touron & Hertzog, 2004a; Touron & Hertzog, 2004b). This is done to reduce the influence of extreme long outliers (perhaps owing to distraction) and extreme short outliers (perhaps owing to guessing). Response time medians were computed for each block (18 trials per block) and were then averaged across five-block sessions (i.e., 90 trials per session). In other words, the mean of every five medians was treated as one measurement point in the analysis. Regarding the accuracy, as aforementioned, three participants who had chance-level accuracy over the course of practice were excluded from further analysis. The rest of the participants maintained their block-level accuracy at or above 90% as required throughout the noun-pair lookup task. No additional analyses were conducted on accuracy.

Means and Standard Deviations

Figures 5 and 6 present the performance trajectories of response time means and standard deviation for the early-change condition and the late-change condition respectively. Looking at Figure 5 and Figure 6, three patterns emerge: (1) performance on the VM task showed little improvement and remained around 2000 milliseconds; (2) performance on the CM task had substantial improvement such that RTs dropped to 1000 milliseconds; (3) apparently, the reduction in RT on the VM task was less than that on the CM task. With regard to RT standard deviations, the lower panels of Figure 5 (early-change condition) and Figure 6 (late-change condition) depict the initially increasing and then decreasing SD values for CM tasks and the initially increasing SD values on the CM task appeared larger than VM SDs in both conditions.

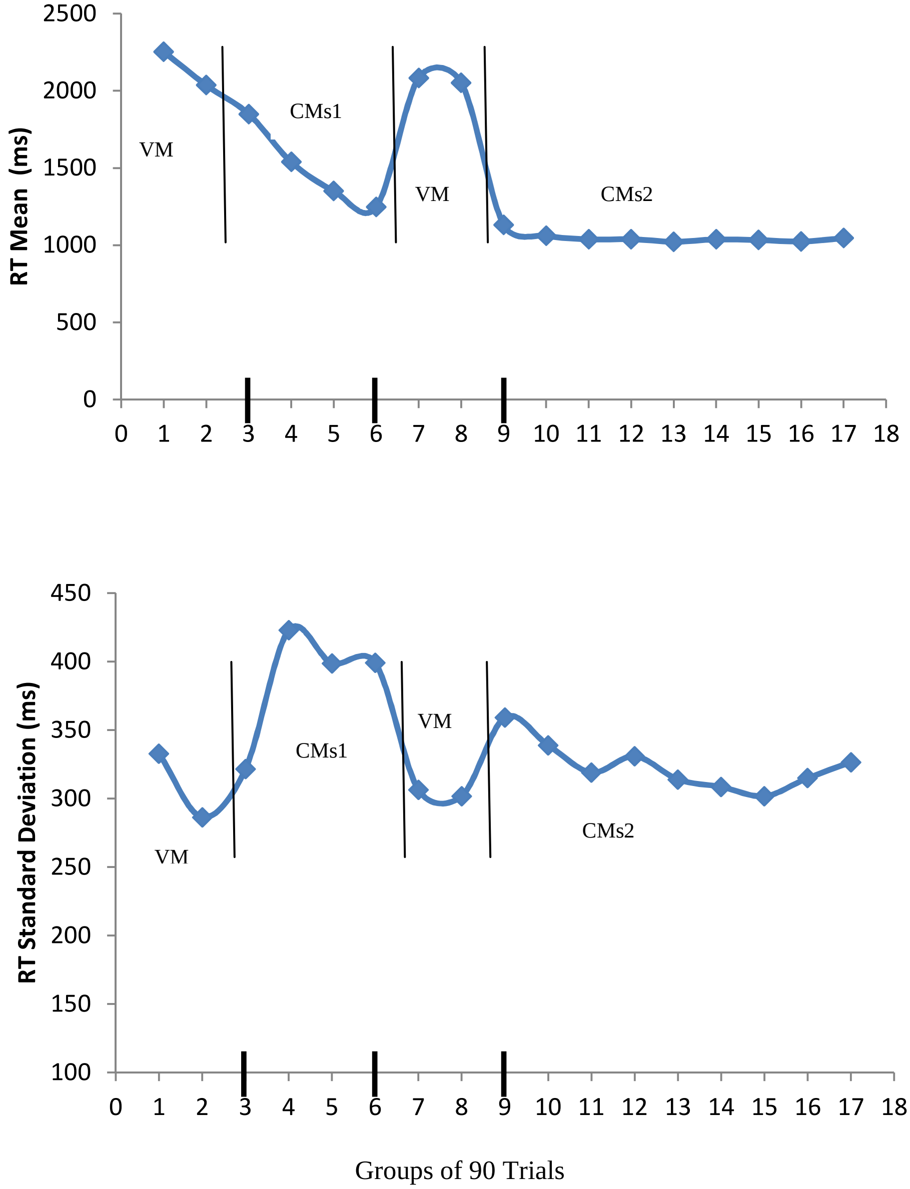


Figure 5. Upper panel: Response time means by practice (90 trials per session) for the early-change condition. Lower panel: Between-subjects standard deviation by practice for the early-change condition. ms = milliseconds.

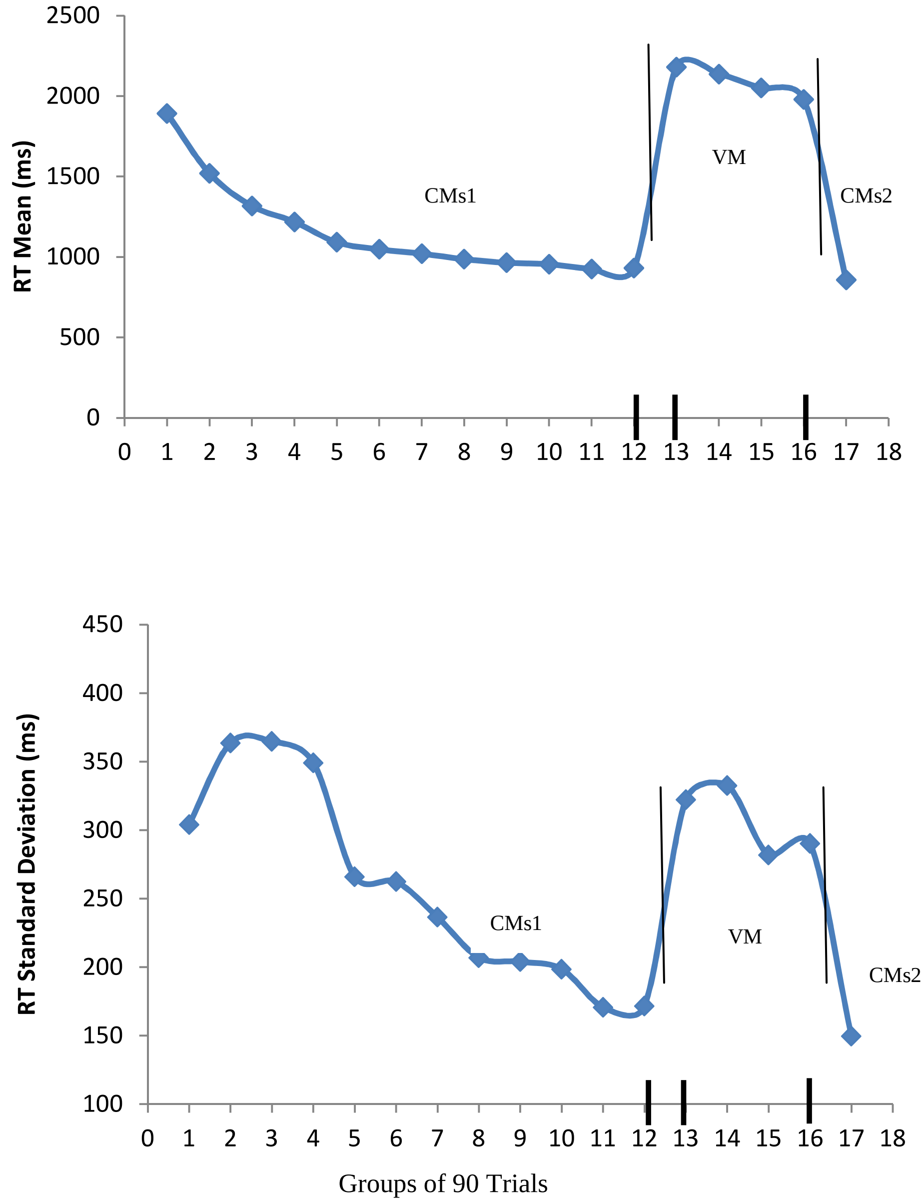


Figure 6. Upper panel: Response time means by practice (90 trials per session) for the late- change condition. Lower panel: Between-subjects standard deviation by practice for the late-change condition. ms = milliseconds.

To examine performance improvements in the VM task, repeated measure ANOVA was conducted comparing RT. In the late-change condition, repeated measure ANOVA on Group 13 to Group 16 (see Figure 6) revealed F (2.6, 254.7) = 49.75, $p < .01$, indicating performance improvement. The degrees of freedom were adjusted due to violation of sphericity. This analysis was not conducted for the early-change condition, given that the practice on the VM task was interrupted by the 20-block CM task.

With practice, substantial reduction in RTs on the CM task occurred in both conditions. In the early-change condition (see Figure 5 upper panel), repeated measure ANOVA was conducted for the two CM sessions separately and indicated significant improvement in both sessions, F (2.1, 211.9) = 200.41, F (4.8, 494.3) = 8.54, both *p*s < .01. The pairwise comparison (after Bonferroni adjustment) showed that in the early-change condition, performance on the first CM session (i.e., CMs1) continuously improved, but in the second CM session (i.e., CMs2), after the 9^{th} group (i.e., 450 CM trials) shown in Figure 5, performance ceased to improve and maintained around 1020 milliseconds.

For the late-change condition (see Figure 6 upper panel), repeated measure ANOVA was conducted for the first 12 groups of CM task practice and confirmed the occurrence of skill acquisition as depicted in the upper panel of Figure 6, F (3.6, 350.4) = 331.3, $p < .01$. The pairwise comparisons indicated that the skill acquisition curve reached its asymptotic level after 720 trials of practice and RT was reduced to below 1000 milliseconds.

Comparing performance trajectories and standard deviations between the early-change condition and the late-change condition, there were two major differences.

Although performance plateaued on the CM task in both conditions, it was reduced to below 1000 milliseconds in the late-change condition, whereas it maintained around 1020 milliseconds in the early-change condition. With regard to performance standard deviation, in the late-change condition, the SDs on the CM task continuously decreased, even after performance plateaued, and the CM SDs were smaller than VM SDs after extensive practice. In the early-change condition, although CM SDs decreased with practice, they were still larger than VM SDs at the end of practice. These results are in line with Ackerman and Woltz's(1994) findings that SDs decreased in the CM task with practice, except that in the late-change condition, CM SDs were smaller than VM SDs at the end of practice. These results matched the characteristics of the noun-pair lookup task and reflected the skill acquisition process. More specifically, because performance on VM task cannot improve as much as that on the CM task, the between-subjects variances remained relatively stable over the course of the VM practice. For the CM task, the initially increasing SDs may be reflective of individual differences in strategy choice but after extensive practice on CM task, more participants adopted a retrieval strategy and therefore individual differences were largely reduced (the detailed analysis on strategy choice is presented below).

Ability, Personality, Adaptability, and Performance Relationship

Performance on the CM task in the two conditions was examined in different segments as required by the analyses conducted. As shown in Figure 4 (p. 43), in both conditions, the first administered CM session was called CMs1 and the second administered CM session was named as CMs2. However, the length of CMs1 and CMs2 were different between the two conditions although the total length of CM task was equal. In the early-change condition, CMs1 consisted of 20 blocks (i.e., 360 trails; 18 trials / block) and CMs2 consisted of 45 blocks. In the late-change condition, CMs1 consisted of 60 blocks and CMs2 consisted of 5 blocks. For further comparison between the two conditions, performance on the CM task was segmented into three parts so that the blocks in CMs1 and CMs2 in the early-change condition can be matched to those in CMs1 and CMs2 in the late-change condition. The three parts are: the first 20 blocks (i.e., the first 360 trials; named as CMpart1), the second 20 blocks (named as CMpart2), and the third 20 blocks (named as CMpart3). Table 4 shows a detailed description of the segments of the CM task between the two conditions.

Table 4. The noun-pair lookup task segments. Upper table: the early-change condition. Lower table: the late-change condition.

<table>
<tr><td>The early-change condition</td><td colspan="2">VM</td><td colspan="4">CM</td><td colspan="2">VM</td><td colspan="9">CM</td></tr>
<tr><td>Group (90 trials/group)</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td></tr>
<tr><td>Session</td><td colspan="2">VM (180 trials)</td><td colspan="4">CMs1 (360 trials)</td><td colspan="2">VM (180 trials)</td><td colspan="9">CMs2 (810 trials)</td></tr>
<tr><td>CMpart</td><td colspan="2"></td><td colspan="4">CMpart1 (360 trials)</td><td colspan="2"></td><td colspan="4">CMpart2 (360 trials)</td><td colspan="4">CMpart3 (360 trials)</td><td></td></tr>
</table>

<table>
<tr><td>The late-change condition</td><td colspan="12">CM</td><td colspan="4">VM</td><td>CM</td></tr>
<tr><td>Group (90 trials/group)</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td></tr>
<tr><td>Session</td><td colspan="12">CMs1 (1080 trials)</td><td colspan="4">VM (360 trials)</td><td>CMs2 (90 trials)</td></tr>
<tr><td>CMpart</td><td colspan="4">CMpart1 (360 trials)</td><td colspan="4">CMpart2 (360 trials)</td><td colspan="4">CMpart3 (360 trials)</td><td colspan="4"></td><td></td></tr>
</table>

Table 5 (the early-change condition) and Table 6 (the late-change condition) present the correlations between predictors and criteria. There were no apparent patterns regarding the relationship between personality, adaptability and performance on the noun-pair task in either condition. However, there were patterns of correlations between perceptual speed, working memory capacity, and performance. For the early-change condition, the correlations between perceptual speed, working memory capacity, and performance were around .3 and significant on the initial groups of CM and VM practice. The correlation between working memory capacity and performance declined with practice, whereas the correlation between the two measures of perceptual speed and performance remained relatively stable over practice.

In the late-change condition, both perceptual speed and working memory correlated with performance on the initial group of CM task, then after 90 trials, only working memory capacity correlated with performance and the effect of perceptual speed decreased. However, after another 270 trials of practice, perceptual speed (measured by the Finding A's test) took over and there was no significant correlation between working memory capacity and performance for the remaining noun-pair lookup task practice. These findings were as expected. At the initial practice of VM and CM tasks, both perceptual speed and working memory capacity were expected to be important. Working memory was likely to be involved in familiarizing oneself with the tasks, and perceptual speed exerted its role on scanning speed and accuracy. With practice, especially in the late-change condition with the CM task, as participants started to memorize the word pairs, working memory capacity had a dominant influence but its influence decreased as skill acquisition transited from Phase 1 to Phase 2 and then, perceptual speed took over, as would be predicted by theories of skill acquisition (e.g., Ackerman, 1988).

The relationships between ability and performance were plotted in Figure 7. For the analyses presented in the following sections (including Figure 7), only Finding A's test was used as the indicator of perceptual speed for two reasons. First, in the early-change condition, the correlation pattern between performance on the Identical Pictures test and the noun-pair task was similar to that between performance on the Finding A's test and the noun-pair task. Second, in the late-change condition, only Finding A's test was correlated with performance on the noun-pair lookup task; Identical Pictures task was not correlated with the criteria. As such, a composite of perceptual speed was not created, and instead I picked the best predictor of the criteria from the two perceptual speed tests. Note that this decision may be risky because of capitalizing on chance but I wanted to proceed with the analysis in a logical way.

The trend lines in both conditions show similar patterns (see Figure 7): at the initial learning stage, working memory played a more important role on CM task performance than perceptual speed did. With practice, the correlation between working memory and task performance decreased and the influence of perceptual speed remained over the course of performance.

*T*able 5. Correlation between predictor variables and criterion variables in the early-change condition.

Variables	*VM*		*CM*				*VM*				*CM*						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Perceptual Speed																	
Finding A's test	-.37	-.41	-.32	-.25	-.22	-.26	-.43	-.26	-.37	-.32	-.28	-.23	-.27	-.30	-.22	-.24	-.26
Identical Pictures	-.30	-.38	-.33	-.27	-.24	-.22	-.32	-.22	-.31	-.29	-.30	-.28	-.27	-.24	-.27	-.27	-.26
Working Memory Capacity																	
Operation Span	-.34	-.28	-.38	-.32	-.22	-.23	-.21	-.23	-.23	-.20	-.17	-.15	-.20	-.19	-.19	-.24	-.23
Conscientiousness																	
Self-efficacy	.06	.13	.08	.08	.07	.06	.07	.01	.17	.01	.06	.04	.05	.04	.04	-.05	-.02
Orderliness	.13	.07	.11	.13	.16	.16	-.02	.11	.07	.02	.04	.00	.01	.04	-.03	-.03	-.01
Dutifulness	.24	.13	.24	.19	.22	.22	.12	.22	.20	.22	.25	.21	.17	.21*	.15	.14	.11
Achievement-striving	.11	.11	.24	.22	.21	.18	.01	.16	.09	.10	.18	.12	.08	.06	.06	.01	-.04
Self-discipline	.14	.13	.24	.34	.31	.27	.05	.23	.07	.15	.22	.16	.15	.13	.12	.07	.10
Cautiousness	.14	.09	.07	.08	.05	.01	-.01	-.04	.11	-.09	-.01	-.04	-.01	-.04	-.09	-.09	-.06
Openness to Experience	.00	.06	.06	.03	.08	.15	.09	.10	.15	.12	.09	.12	.06	.12	.17	.10	.05
Adaptability																	
Crisis	.15	.20	.20	.18	.17	.19	.15	.13	.26	.20	.24	.27	.30	.26	.25	.21	.19
Cultural	-.04	-.06	.12	.09	.11	.15	-.01	.16	.02	.13	.14	.17	.10	.11	.13	.03	.06
Work Stress	-.06	-.02	-.10	-.11	-.14	-.14	.01	-.12	.03	-.09	-.04	-.05	-.01	-.05	-.03	-.04	-.04
Interpersonal	.05	.08	.18	.06	.08	.14	.10	.14	.12	.18	.18	.21	.16	.19	.23	.11	.14
Learning	.08	.09	.21	.20	.21	.23	.03	.19	.14	.15	.24	.21	.15	.12	.13	.09	.08
Physical	-.05	.03	.08	.03	.05	.03	.02	.04	.03	.04	.09	.13	.08	.04	.01	.06	.08
Uncertainty	-.09	.05	-.02	-.02	-.07	-.07	.06	-.08	.05	-.03	.01	.04	.03	.00	.00	-.04	.00
Creativity	.04	.16	.21	.11	.12	.15	.11	.10	.17	.12	.13	.15	.10	.08	.10	.06	.03

Note. N = 103. Correlations greater than .19 were significant at .05 level; correlations greater than .25 were significant at .01 level. The criterion variables are named by the version of the task (i.e., VM or CM) followed by the number of group (90 trials) in which they were administered.

Table 6. Correlation between predictor variables and criterion variables in the late-change condition.

Variables	CM												VM				CM
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Perceptual Speed																	
Finding A's test	-.25	-.14	-.18	-.20	-.21	-.26	-.24	-.22	-.21	-.23	-.18	-.17	-.16	-.27	-.22	-.16	-.27
Identical Pictures	-.26	-.05	-.03	-.02	.02	.01	-.11	-.08	-.06	-.12	-.16	-.17	-.29	-.20	-.17	-.19	-.25
Working Memory Capacity																	
Operation Span	-.28	-.34	-.22	-.23	-.18	-.13	-.18	-.04	-.01	-.04	-.08	-.07	-.04	-.19	-.17	-.18	-.09
Conscientiousness																	
Self-efficacy	-.08	.05	.06	-.01	-.04	.03	-.04	.03	-.10	-.09	-.07	-.07	-.12	-.11	-.07	-.12	-.04
Orderliness	-.13	.04	.04	.10	.10	.15	.04	.14	.09	.13	.11	.11	-.09	-.09	-.08	-.07	.08
Dutifulness	-.05	.11	.17	.14	.04	.04	.09	.06	.03	.01	.00	-.03	-.07	-.10	-.05	-.09	-.01
Achievement-striving	-.21	-.04	.01	.04	.04	.07	.04	.13	.05	.06	.11	.12	-.04	-.09	-.07	-.12	.11
Self-discipline	-.05	.16	.17	.16	.14	.19	.14	.19	.10	.11	.08	.10	-.06	-.05	-.06	-.09	.07
Cautiousness	-.02	.14	.09	.05	.02	.07	.02	.04	.06	.06	.02	.03	-.16	-.14	-.13	-.20	.01
Openness to Experience	-.16	-.15	-.19	-.22	-.24	-.15	-.05	-.15	-.19	-.15	-.19	-.09	-.01	-.06	-.05	-.04	-.13
Adaptability																	
Crisis	-.11	-.07	-.05	-.02	-.05	-.08	-.09	.01	.00	-.10	-.02	-.02	-.11	-.09	-.13	-.15	-.03
Cultural	.00	-.04	-.05	-.12	-.19	-.09	-.02	-.08	-.08	-.14	-.19	-.07	.04	.01	.00	.01	-.10
Work Stress	-.05	-.01	.04	-.02	-.04	.00	-.01	.04	-.05	-.10	-.08	-.07	-.12	-.10	-.10	-.17	-.06
Interpersonal	-.03	-.10	-.08	-.18	-.20	-.11	-.08	-.11	-.08	-.14	-.13	-.11	.02	.02	.03	.04	-.12
Learning	-.08	-.05	.01	.02	.07	.06	.02	-.02	-.03	-.02	-.08	-.02	.02	-.03	.01	.03	-.01
Physical	-.04	.03	-.01	-.03	-.08	-.07	-.13	-.12	-.12	-.19	-.15	-.13	-.13	-.09	-.13	-.16	-.10
Uncertainty	-.05	-.09	-.10	-.14	-.17	-.13	-.10	-.08	-.14	-.19	-.12	-.10	-.01	.01	.00	-.05	-.09
Creativity	-.20	-.17	-.12	-.07	-.04	-.01	-.04	.00	-.06	-.06	-.11	-.09	-.03	-.05	-.14	-.10	-.04

Note. N = 103. Correlations greater than .19 were significant at .05 level; correlations greater than .25 were significant at .01 level. The criterion variables are named by the version of the task (i.e., VM or CM) followed by the number of group (90 trials) in which they were administered.

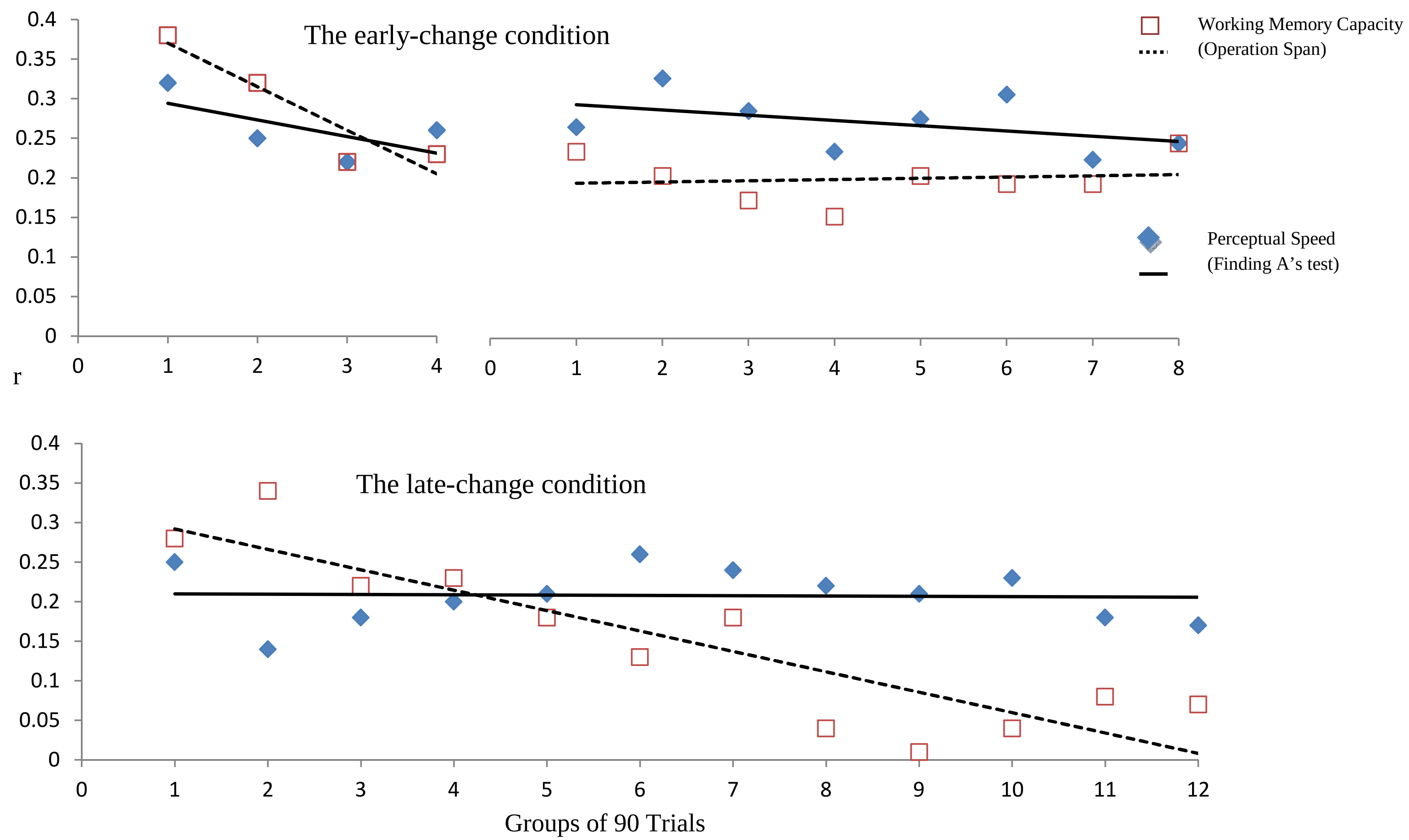


Figure 7. Correlations between ability and CM task performance by practice.
Note. The x-axis is label by group of 90 trials in order of administration. In the early-change condition, CM task was administered in two sessions separated by an intervening group of VM trials. Therefore the trend shows the two sessions separately.

The analyses presented above first examined predictors and criteria separately and then explored the relationship between ability, personality factors, adaptability and performance on the noun-pair lookup task. In the following sections, explicit tests of the hypotheses are presented.

The Moderation Effect of Performance Stage

Recall that one difference between the early-change and the late-change condition was the performance stage at which a change was introduced. In the early-change condition, the unexpected change from CM to VM task was introduced after 360 trials (i.e., 4 groups of 90 trials) of practice; in the late-change condition, the change from CM to VM task occurred after 1080 trials (i.e., 12 groups of 90 trials; see Figure 4, p 43). Hypothesis 1 stated that the relationship between working memory capacity and post-change task performance should be stronger when a change from the CM task to the VM task is introduced at early stages (i.e., when performance is still improving) than when it is introduced at late stages (i.e., when performance shows little improvement).

To explore the moderating effect of performance stage, hierarchical multiple regression was conducted. Performance on the first group of the VM task was regressed onto the performance on the last group of the CM task right before the change, working memory capacity, perceptual speed, condition, and the interactions between condition and the two ability factors. Condition was dummy coded, with the early-change condition coded as 0 and the late-change condition coded as 1. Working memory capacity and perceptual speed were standardized and interaction terms were created by multiplying the centralized ability factors and dummy coded condition.

Table 7 presents the results of the hierarchical regression. After controlling for performance on the CM task before the change, both condition and perceptual speed were significant predictors of post-change VM performance. No significant interactions between condition and ability factors were found and thus Hypothesis 1, that performance stage at which a change was introduced moderated the relationship between working memory capacity and post-change performance, was not supported.

Although no interactions were found, the main effects of perceptual speed and condition were as expected and interesting. After controlling for pre-change CM performance, perceptual speed was found to be negatively predictive of post-change VM performance. Satisfactory performance on the VM task requires scanning speed and accuracy, which relies on perceptual speed. Therefore, the faster a participant's perceptual speed ability, the better she or he performed on the post-change VM task with shorter RTs.

The regression coefficient of condition was positive. Given that the early-change condition was coded as 0 and the late-change condition was coded as 1, this positive value indicated that controlling for pre-change CM task performance, participants had longer RTs on the post-change VM task when the change was introduced at late stages of the CM practice than when the change was introduced at early stages of the CM practice. In other words, participants in the late-change condition showed more performance decrements. When the change was introduced at the late stage of skill acquisition, participants had presumably already reached performance asymptote and therefore had more to lose when a change unexpectedly occurred.

The moderation effect of performance stage on the relationship between personality traits and the post-change task performance was also examined. Conscientiousness was computed at its two main facets of interest: achievement (i.e., the composite of self-efficacy, achievement-striving, and self-discipline) and dependability (i.e., the composite of orderliness, dutifulness, and cautiousness). After controlling for pre-change CM task performance, only condition was a significant negative predictor of the VM task performance (β = .36, p < .01).

Table 7. Regression of post-change VM performance on working memory capacity, perceptual speed, condition, and interactions between condition and ability factors, controlling for pre-change CM performance.

Predictor	ΔR^2	β	p
Step 1	.09		
CM		.30	<.001
Step 2	.14		
CM		.41	<.001
Condition		.35	<.001
Working memory		-.06	.378
Perceptual Speed		-.19	.005
Step 3	.00		
CM		.40	<.001
Condition		.34	<.001
Working memory		-.10	.307
Perceptual Speed		-.22	.011
Interaction (condition * WMC)		.05	.608
Interaction (condition * PS)		.05	.526
Total R^2	.23		<.001

Note. N = 194. PS = Perceptual Speed, WMC = Working Memory Capacity. Condition: the early-change condition was coded as 0 and the late-change condition was coded as 1.

Strategy Use

Owing to the nature of the CM noun-pair task, either a scanning or a retrieval strategy can be employed to reach a satisfactory performance level. As the literature suggests (e.g., Ackerman & Woltz, 1994; Rogers & Gilbert, 1997), participants use different strategies for this task. With practice, some participants shift from a scanning strategy to a retrieval strategy and show a significant reduction in their response times. Others may stick to a scanning strategy over the course of performance and have little or no performance improvement.

Hypotheses 2 and 3 stated that people who are high on openness to experience and people who are low on the dependability facet of conscientiousness would choose the retrieval strategy more quickly in the CM task and that openness to experience and dependability would predict strategy use above and beyond working memory capacity and perceptual speed. Before testing the two hypotheses, I will first discuss the criterion used for strategy classification and report task performance differences between scanners and retrievers.

Strategy Classification and Shift

The self-report strategy measure did not provide enough information for further analysis. Keys for coding the scanning and the retrieval strategy were first generated, for example “look up” would be an indication of a scanning strategy and “recall from memory” would imply a retrieval strategy. However, after a careful examination, it was found that participants were not specific enough on the version of the noun-pair lookup task when reporting their strategy use. For example, some of them reported that they just scanned the word pairs but their RTs on the CM task suggested otherwise (i.e., their RTs were less than 1000 ms which was only possible by employing a retrieval strategy). To identify the strategies that participants used in this study, Ackerman and Woltz's (1994) categorization method was used. Participants' performance on the recall test was also examined to provide further information about strategy. Presumably, retrievers should have better performance than scanners on the recall test, because they needed to memorize the word pairs to employ the retrieval strategy.

For the VM task, only the scanning strategy is applicable and studies have shown (e.g., Ackerman & Woltz, 1994; Rogers & Gilbert, 1997) RTs on the VM task were never less than 1s. As such, it was assumed that the scanning strategy is associated with RTs longer than 1s and this criterion was adopted to categorize participants into scanners and retrievers in the CM task. For the CM task, which affords the flexibility of using either scanning or retrieval strategy. If a participant's RTs were not reduced to less than 1s, she or he should be using a scanning strategy; if a participant's RTs were less than 1s, she or he should be using a retrieval strategy. Using 1s as the criterion to dichotomize participants into scanners or retrievers, I further examined strategy shift (e.g., Rogers & Gilbert, 1997) and the factors that determine strategy shift. For each condition, the first 1080 trials of CM task were segmented into three parts: the first 360 trials (i.e., CMpart1), the intermediate 360 trials (i.e., CMpart2) and the last 360 trials (i.e., CMpart3). Note that performance of the last group of the CM task was not included because in the late-change condition, it was preceded by the VM task. In each part, participants' mean RTs were calculated, and if they were less than 1s, the participant was categorized as a retriever, otherwise they were categorized as a scanner.

Table 8 presents the strategy shift in the CM task for each condition. For both conditions, there were fewer scanners and more retrievers over the course of practice, indicating strategy shift over time. Between conditions, it seemed that the proportion of participants using different strategies did not differ for CMpart 1 and CMpart2; in CMpart3, there seemed to be more retrievers in the late-change condition than in the early-change condition, which could explain the RT difference at the end of the CM task between two conditions. Recall that although participants in both conditions reached asymptotic performance, in the early-change condition performance plateaued at around 1020 ms whereas in the late-change condition performance plateaued at 940 ms. However, the Chi-Square analysis on scanners and retrievers revealed that difference on the proportion of retrievers between the late-change condition at the end of CM task and the early-change condition was only marginally significant ($\chi^2 = 3.30$, $p = .07$).

Table 8. Strategy classification for each part of the CM task by condition.

	The early-change condition			The late-change condition		
	# Scanner	# Retriever	% Scanner	# Scanner	# Retriever	% Scanner
CMpart1	98	4	95.15	95	3	95.96
CMpart2	49	54	47.57	44	54	44.44
CMpart3	42	61	40.78	28	70	28.28

Note. The early-change condition, $N = 103$. The late-change condition, $N = 98$.

Scanners vs. Retrievers

To further examine the difference between scanners and retrievers after extensive CM practice, the performance of scanners and retrievers was compared on CMpart3.

Figure 8 displays the histograms of mean RTs in CMpart3 in the early-change condition and the late-change condition respectively. RT distributions in both conditions supported the categorization of participants into retrievers and scanners based on the 1s criterion, although they were not bimodal. Even after extensive practice, there were still participants whose performance (i.e., RT) was not improved to the less-than-1s level, which should be due to strategy used.

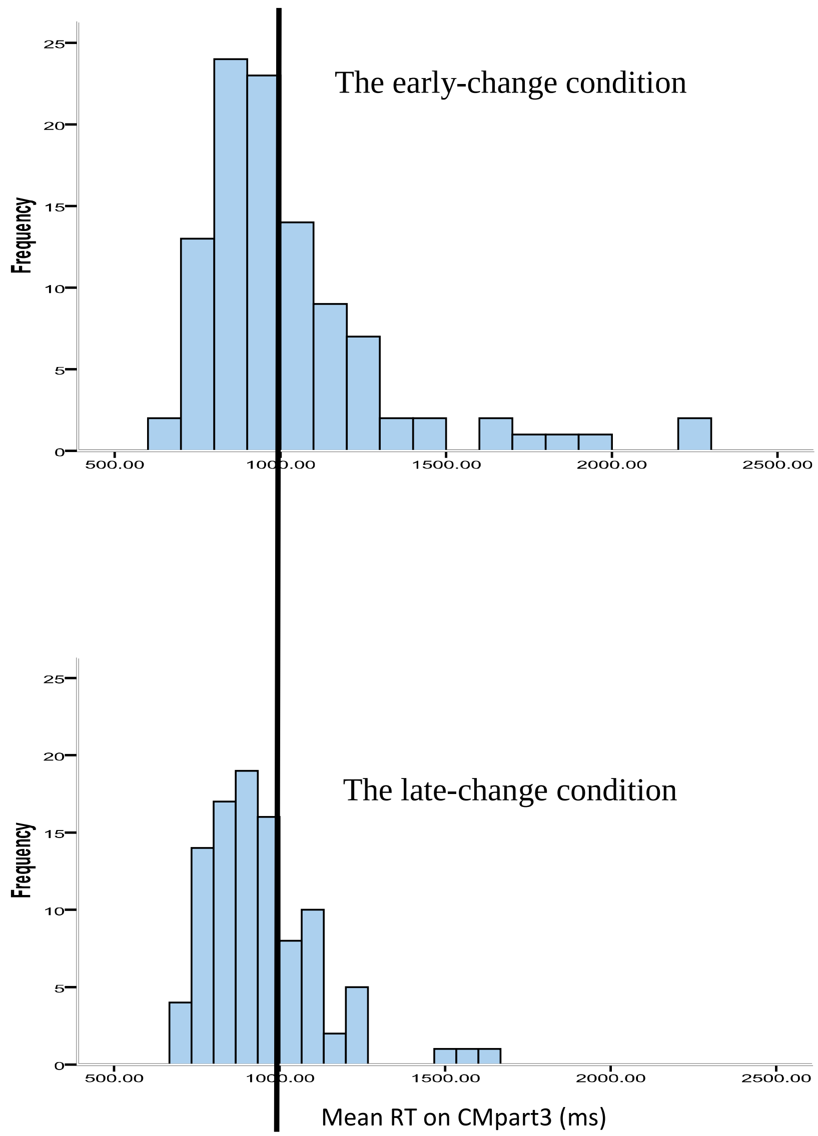
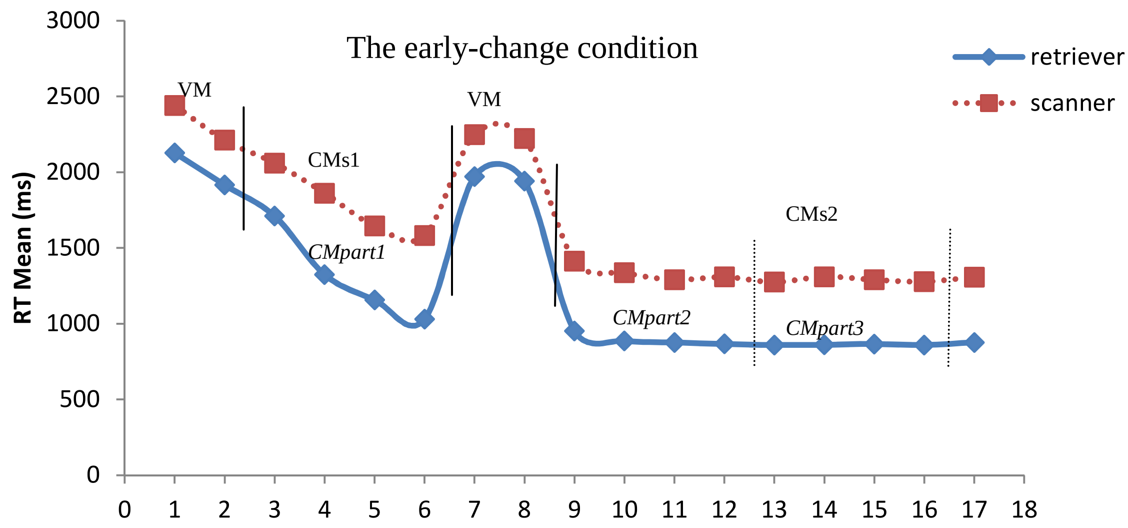


Figure 8. Histograms of the mean response time on CMpart3 in the two conditions. Early-change condition (n = 103); late-change condition (n = 98).

Based on the 1s criterion, scanners and retrievers' performance on the noun-pair task (mean RTs and between-subjects SDs) is presented in Figure 9 for the early-change condition and in Figure 10 for the late-change condition. As shown, in both conditions, scanners had shallower performance improvement than retrievers. As a post-hoc check, the differences between scanners and retrievers in terms of their mean RT in the two conditions were examined. At the end of CMpart3, in the early-change condition, mean RTs were 1264.48 milliseconds and 858.28 milliseconds for scanners and retrievers, respectively and the RT difference was significant (t (45.35) = 3.90, $p < .01$). In the late-change condition, the mean RT for scanners was 1124.66 milliseconds and it was 855.76 milliseconds for retrievers, and the RT difference was significant, t (33.81) = 7.99, $p < .01$. Regarding the between-subjects SDs, in the early-change condition, variances among retrievers were substantially reduced over time, whereas variances among scanners remained stable (see Figure 9). The difference in variances between scanners and retrievers over the course of CMpart3 practice were all significant ps < .01. In the late-change condition, the difference between scanners and retrievers on between-subjects variance was less dramatic although scanners still had more variance (see Figure 10). The variances of scanners and retrievers were not equal over the course of CMpart3 practice, ps < .05 (t-test equal variance assumed was rejected).

The mean RTs and between-subjects SDs for scanners and retrievers suggested that scanners, especially scanners in the late-change condition, may actually have been using a combination of scanning and retrieval strategies, given that both their mean RTs and between-subjects SDs were reduced with practice. The categorization of participants was partly supported by their performance on the recall test. High recall accuracy implied that a participant had memorized most of the word pairs in the CM task and that she or he was therefore more likely to use a retrieval strategy. Comparing the two conditions, recall accuracy was significantly different between the early-change condition and the late-change condition (t (181.25) = -4.17, p < .01). The mean recall accuracy for the early-change condition was 75% and it was 88% for the late-change condition. In the early-change condition, the recall accuracy for scanners was 63% and it was 83% for retrievers and the difference was significant (t (58.78) = -3.90, p < .01). In the late-change condition, the recall accuracy were 82% and 90% for scanners and retrievers respectively (t (35.21) = -1.69, p = .10). In the late-change condition, recall accuracy did not differ between scanners and retrievers, suggesting that scanners may indeed have been using a combination of scanning and retrieval strategies.



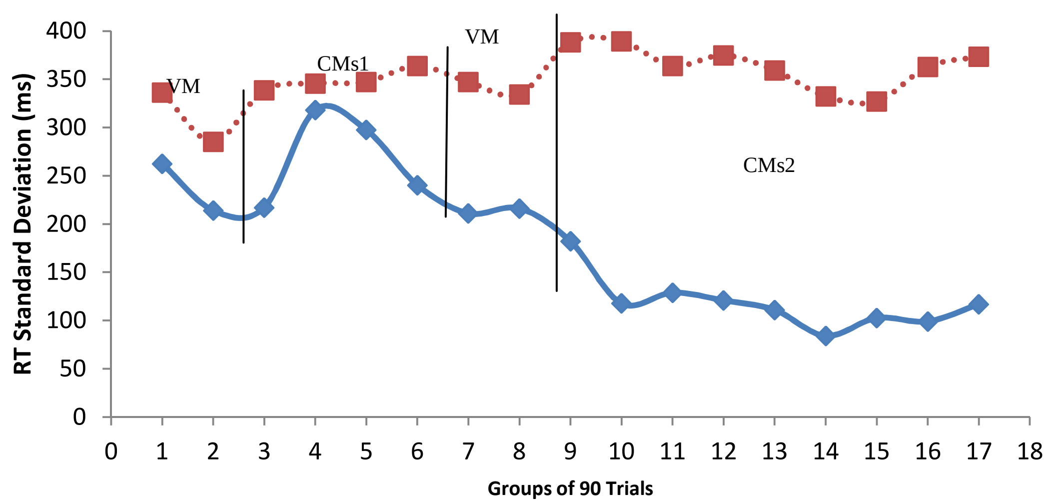


Figure 9. Upper panel: response time means by scanners and retrievers and practice in the early-change condition. Lower panel: between-subjects standard deviations by scanners and retrievers and practice in the early-change condition.

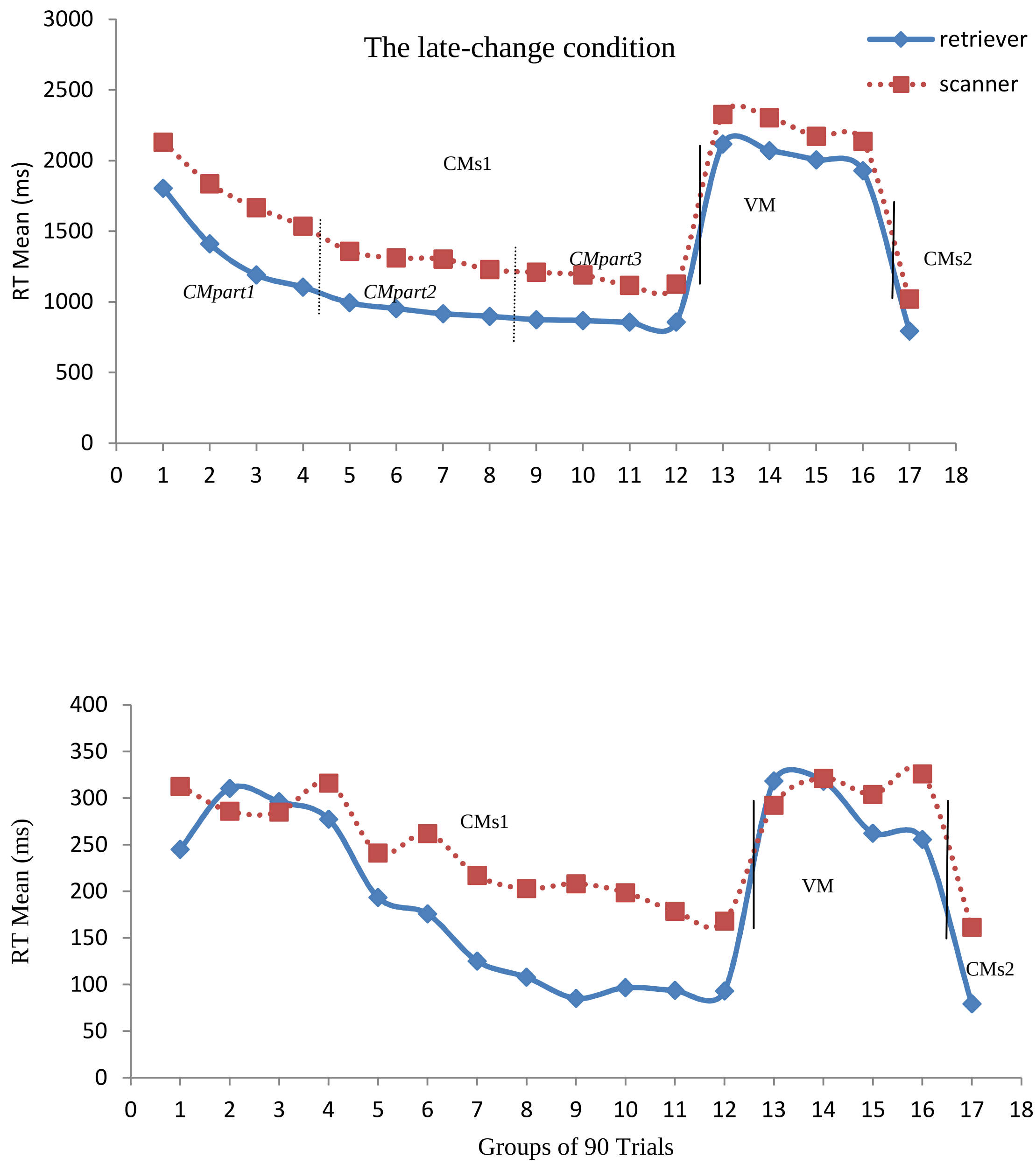


Figure 10. Upper panel: response time means by scanners and retrievers and practice in the late-change condition. Lower panel: between-subjects standard deviations by scanners and retrievers and practice in the late-change condition.

Ability, Personality, and Strategy Use

What determined a participant's strategy choice? This part of analysis examined the relationship between ability, personality and strategy choice. First, for each condition, scanners and retrievers were compared on ability and personality factors. Second, regression analysis was conducted to examine determinants of strategy choice. However, the analyses were only conducted for CMpart2 and CMpart3 to explore whether predictors of strategy use changed over the course of CM practice. The regression was not conducted for CMpart1, given that there was no strategy choice during the first part of the CM task.

Tables 9 (the early-change condition) and Table 10 (the late-change condition) present comparisons between scanners and retrievers on ability, personality factors and adaptability in each condition. As shown, in the early-change condition, for CMpart2, retrievers were higher in perceptual speed ability than were scanners (t (98) = 3.41, p < .01). On learning and physical facets of adaptability, scanners had higher scores (t (101) = -2.26, p = .03 on the learning facet; t (101) = -2.02, p = .05 on the physical facet). For CMpart3, retrievers had faster perceptual speed ability than scanners (t (98) = 3.39, p < .01), but had lower scores on the crisis facet of adaptability (t (101) = -2.58, p = .01) and on the interpersonal facet of adaptability (t (101) = -2.34, p = .02). However, in the late-change condition, none of the differences between scanners and retrievers on ability, personality, and adaptability reached significance. The difference on perceptual speed in favor of retrievers was marginally significant in CMpart2 (p= .07).

Table 9. Comparison between scanners and retrievers on individual differences factors in the early-change condition.

	CMpart2			CMpart3		
	Scanner	Retriever	*p*	Scanner	Retriever	*p*
Perceptual Speed						
Finding A's test	27.60	32.69	.001	27.23	32.34	.001
Working Memory Capacity						
Operation Span	47.76	52.41	.105	47.95	51.74	.196
Conscientiousness						
Achievement	110.84	108.04	.340	111.54	107.87	.217
Dependability	106.90	107.26	.906	106.79	107.30	.870
Openness to experience	39.73	38.07	.161	40.17	37.97	.067
Adaptability						
Crisis	23.18	22.11	.156	23.76	21.84	.011
Cultural	22.06	21.06	.059	21.79	21.36	.436
Work Stress	15.33	15.31	.989	15.26	15.36	.910
Interpersonal	29.84	28.94	.181	30.29	28.74	.021
Learning	35.92	33.91	.026	35.90	34.15	.056
Physical	32.04	29.91	.046	31.55	30.49	.335
Uncertainty	31.24	29.57	.081	30.98	29.95	.294
Creativity	19.04	17.98	.077	18.93	18.18	.221

Note. $N = 103$.

Table 10. Comparison between scanners and retrievers on individual differences factors in the late-change condition.

	CMpart2			CMpart3		
	Scanner	Retriever	*p*	Scanner	Retriever	*p*
Perceptual Speed						
Finding A's test	29.75	32.30	.074	29.64	31.77	.177
Working Memory Capacity						
Operation Span	46.98	52.02	.125	46.25	51.16	.176
Conscientiousness						
Achievement	111.18	108.31	.386	110.57	109.21	.710
Dependability	109.55	107.98	.613	109.39	108.40	.771
Openness to experience	38.50	40.61	.079	38.36	40.19	.168
Adaptability						
Crisis	21.70	22.01	.717	22.00	21.83	.858
Cultural	21.59	21.94	.526	22.07	21.67	.515
Work Stress	14.98	15.70	.433	15.21	15.44	.823
Interpersonal	28.77	29.70	.204	29.21	29.31	.902
Learning	34.14	33.42	.473	33.85	33.70	.886
Physical	30.52	30.64	.900	29.25	31.12	.084
Uncertainty	30.04	31.06	.320	29.64	30.99	.230
Creativity	17.86	17.78	.903	17.36	18.00	.404

Note. $N = 98$.

Hypothesis 2 and 3 stated that people who are high on openness and people who are low on the dependability facet of conscientiousness would choose the retrieval strategy more quickly in the CM task. To further explore the determinants of strategy choice and test Hypotheses 2 and 3, multiple linear regression analysis was conducted for the two conditions separately. CM task performance was the dependant variable and the predictors were perceptual speed, working memory capacity, openness to experience and the two dimensions of conscientiousness. The rationale for using CM task performance as the dependant variable was that the faster a participant's RT on the CM task, the more likely she or he used a retrieval strategy. Because a scanning strategy cannot reduce RTs as much as a retrieval strategy can on the CM task.

To examine whether the patterns of the predictive power of the ability and personality factors on strategy use, if there were any, remained stable over the course of performance, the multiple linear regression analysis was conducted separately for CMpart2 (the intermediate phase of CM task practice) and CMpart3 (the ending phase of CM task practice). The RT means for CMpart2 and Cmpart3 were used as the dependent variable in the corresponding regression. In the early-change condition, as shown in Table 11, for CMpart2 and CMpart3, perceptual speed and working memory capacity had negative relationships with CM performance. The results suggested that participants with higher working memory capacity and faster perceptual speed had shorter RTs on CMpart2 and CMpart3 and therefore were more likely to be using a retrieval strategy.

In the late-change condition, as presented in Table 12, perceptual speed was significantly negatively related to CMpart2 performance and openness to experience was marginally negatively related to CMpart2 performance. In CMpart3, the negative relationship between openness to experience and CMpart3 performance became statistically significant, whereas the predictive power of perceptual speed was only marginally significant. As such, in the late-change condition, participants with faster perceptual speed and participants who were high on openness to experience showed shorter RTs on the CM task and therefore were more likely to be using a retrieval strategy.

The results on the multiple linear regression analysis partly supported Hypothesis 2 but did not support Hypothesis 3. Openness to experience was found to be related to the use of a retrieval strategy, but only in the late-change condition for CMpart3. It seems that the performance stage at which an unexpected change was introduced had a different influence on the roles individual differences factors played in the two conditions, and affected participants' strategy choice differently. No relationship between conscientiousness and strategy choice was found and Hypothesis 3 is not supported.

Table 11. Multiple linear regression results in the early-change condition for CM task part 2 and part 3.

	Total R^2	β	p
CMpart 2			
Model	.15		
Perceptual Speed		-.26	.009
Working Memory Capacity		-.23	.021
Openness to Experience		.09	.376
Achievement		.13	.332
Dependability		-.01	.935
CMpart3			
Model	.14		
Perceptual Speed		-.25	.013
Working Memory Capacity		-.24	.015
Openness to Experience		.13	.238
Achievement		.05	.714
Dependability		.00	.985

Note. N = 100.

Table 12. Multiple linear regression results in the late-change condition for CM task part 2 and part 3.

	Total R^2	β	p
CMpart 2			
Model	.13		
Perceptual Speed		-.23	.027
Working Memory Capacity		-.13	.222
Openness to Experience		-.19	.078
Achievement		.22	.114
Dependability		-.08	.581
CMpart3			
Model	.10		
Perceptual Speed		-.20	.058
Working Memory Capacity		-.06	.546
Openness to Experience		-.23	.037
Achievement		.17	.240
Dependability		-.07	.615

Note. N = 94.

The Mediation Effect of Adaptability

Hypothesis 4 and 5 were proposed based on the I-ADAPT theory that adaptability will be positively related to working memory capacity, perceptual speed, conscientiousness, and openness to experience and it will mediate the relationship between the distal ability and non-ability traits (working memory capacity, perceptual speed, conscientiousness and openness to experience) and adaptive performance.

To examine the mediating effect of adaptability, Baron and Kenny (1986) procedure was followed, which include three steps: first regressing adaptability (i.e., the mediator) on the ability and personality factors; second, regressing post-change performance on the VM task on the ability and personality factors; and third, regressing the post-change performance on the VM task on adaptability, ability and personality factors. The mediation of adaptability would be established if the following conditions hold: first, ability and personality factors must be related to adaptability in the first regression equation; second, the ability and personality factors must be related to the dependant variable (i.e., post-change VM performance) in the second regression equation; third, adaptability must be related the dependant variable in the third equation; last but not least, the effect of ability and personality traits on the dependant variable must be smaller in the third equation than in the second equation.

Following the procedure, adaptability was first regressed on perceptual speed, working memory capacity, achievement and dependability dimensions of conscientiousness and openness to experience. Condition was not added as a predictor because the relationship between adaptability and ability and personality factor, if there was any, was not expected to be related to the experiment condition. As presented in

Table 13, only personality traits were significant predictors of adaptability. The two dimensions of conscientiousness, achievement and dependability, showed opposite relationships with adaptability. As such, Hypothesis 4 was partly supported in that adaptability was related to personality factors but not with ability factors.

Table 13. Regression of adaptability on ability and personality traits.

Predictor	Total R^2	β	*p*
Model	.45		
Perceptual Speed		-.06	.280
Working memory		.05	.385
Achievement		.78	<.001
Dependability		-.38	<.001
Openness		.13	.033

Note. N = 194.

The second step was to regress post-change performance on the VM task on the ability, personality factors, condition and the interaction terms, controlling for pre-change CM performance. As reported in Table 14, perceptual speed had a significant relationship with post-change VM performance.

Table 14. Regression of post-change VM performance on condition, ability, personality, and interaction terms, controlling for pre-change CM performance.

Predictor	ΔR^2	β	*p*
Step 1	.09		
CM		.30	<.001
Step 2	.14		
CM		.41	<.001
Condition		.34	<.001
Perceptual Speed		-.18	.007
Working memory Capacity		-.06	.351
Achievement		-.06	.517
Dependability		.03	.369
Openness to Experience		.06	.384
Step 3	.02		
CM		.38	<.001
Condition		.33	<.001
Perceptual Speed		-.23	.010
Working memory Capacity		-.12	.227
Achievement		-.14	.289
Dependability		.18	.142
Openness to Experience		.15	.149
Interaction(condition * PS)		.07	.409
Interaction (condition * WMC)		.06	.565
Interaction (condition * Achievement)		.12	.317
Interaction (condition * Dependability)		-.22	.082
Interaction (condition * Openness)		-.12	.235
Total *R*	.25		

Note. *N* = 194. PS = Perceptual Speed, WMC = Working Memory Capacity, Achievement and Dependability are two facets of Conscientiousness.

The third step was to examine whether adaptability mediated the relationship between ability, personality factors and adaptive performance. Post-change VM performance was regressed on adaptability as well as on ability and personality traits, condition, and the interaction terms, controlling for pre-change CM performance. Table 15 presents the regression results. Adaptability was not a significant predictor of the VM task performance, neither was its interaction with condition. As such, there was no evidence that adaptability mediated the relationship between distal ability and personality traits and adaptive performance. Hypothesis 5 was not supported.

However, with the inclusion of adaptability and its interaction with condition, the interaction between dependability and condition reached significance (see Table 15). This interaction was graphed on one standard deviation above and below the mean of dependability, as part of a post-hoc analysis. For the rest of the predictors, their means were entered into the regression equation. As shown in Figure 11, the post-change performance of participants with relatively high scores on the dependability dimension of conscientiousness seemed similar regardless of when the change was introduced; whereas for the participants in the two conditions with relatively low scores on dependability, performance decrements seemed smaller when the change was introduced early. This interaction further revealed the harmfulness of a change introduced at a later stage of learning compared to a change introduced at an early stage of learning: even the people who were unlikely to stick to old rules were not adaptive to the new task. More evidence is needed to confirm the above inference, given that the task used in this study is a relatively simple one.

Table 15. Regression of post-change VM performance on condition, ability, personality, adaptability, and interaction terms, controlling for pre-change CM performance.

Predictor	ΔR^2	β	*p*
Step 1	.09		
CM		.30	<.001
Step 2	.14		
CM		.41	<.001
Condition		.35	<.001
Perceptual Speed		-.18	.009
Working memory Capacity		-.06	.338
Achievement		-.10	.390
Dependability		.05	.589
Openness to Experience		.05	.445
Adaptability		.05	.567
Step 3	.02		
CM		.38	<.001
Condition		.33	<.001
Perceptual Speed		-.22	.018
Working memory Capacity		-.13	.227
Achievement		-.25	.127
Dependability		.23	.081
Openness to Experience		.13	.195
Adaptability		.15	.243
Interaction(condition * PS)		.06	.482
Interaction (condition * WMC)		.06	.516
Interaction (condition * Achievement)		.23	.155
Interaction (condition * Dependability)		-.27	.044
Interaction (condition * Openness)		-.10	.316
Interaction (condition * Adaptability)		-.16	.224
Total R^2	.25		

Note. *N* = 194. PS = Perceptual Speed, WMC = Working Memory Capacity, Achievement and Dependability are two facets of Conscientiousness.

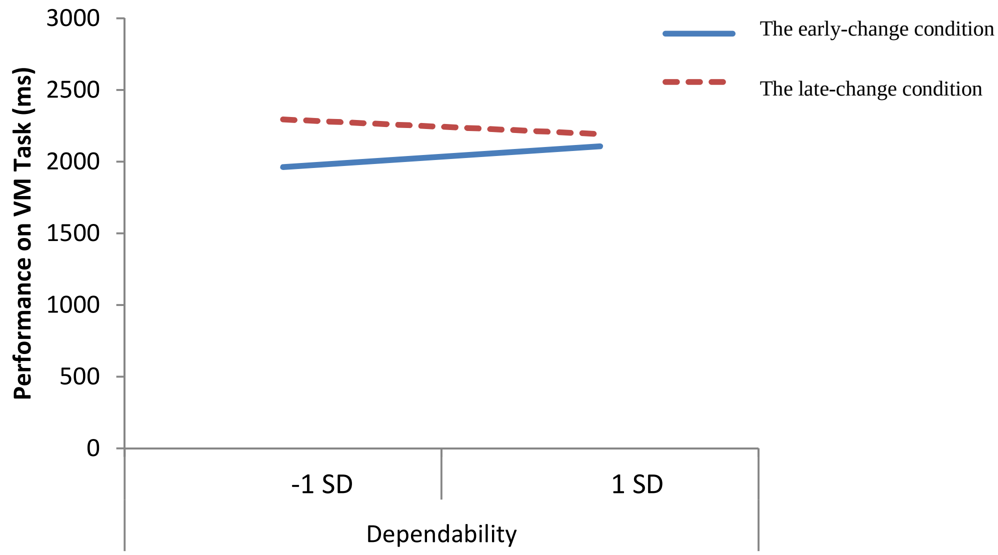


Figure 11. The interaction between dependability and condition.

The Effect of VM Practice

One difference between the early-change condition and the late-change condition was the exposure to the VM version at the beginning of the noun-pair lookup task. That is, in the early-change condition, participants started with 2 groups of VM task first, which was followed by 4 groups of CM task (i.e, 360 trials). In the late-change condition, there was no exposure to the VM version at the beginning and participants started with the CM version directly.

Hypothesis 6 stated that starting with the VM task, compared with starting with the CM task will make people more likely to switch to a retrieval strategy at early stages of the CM task (i.e., during the first 360 trials, or CMpart1 across both conditions). Hypothesis 6 was not supported given that at the early stage of the CM task (i.e., CMpart1), there were very few participants using a retrieval strategy in both conditions (see Table 8, p. 67): only 4 participants in the early-change condition and 3 participants in the late-change condition were categorized as retrievers.

The effect of VM practice was further examined in terms of whether it facilitated performance on the following CM task. Performance on the first group of the CM task (i.e., the 5 blocks that followed the VM task in the early-change condition) and the fourth group (i.e., the last 5 blocks of CMs1 in the early-change condition) of the CM task was compared between two conditions. The independent sample *t*-test revealed that there was no difference between the two conditions in either the first group of CM task or the fourth group of CM task: t (199) = -1.07 and t (199) = .39, respectively, ps > .28.

Repeated measures ANOVA was also conducted to examine whether VM practice had an impact on the pattern of performance improvement. No difference was found between the two conditions. For the first 360 trials (i.e. CMpart1) of the CM task performed, participants in the two conditions showed a similar pattern of improvement: the main effect of practice was significant, F (1.96, 389.57) = 426.92, p < .001.There was no main effect of condition, F (1, 199) = .001, p =.98, and there was no interaction between practice and condition, F (1.96, 389.57) = 1.50, p =.23.

CHAPTER 5

DISCUSSION

This study investigated individual differences in adaptive performance build on the Individual Adaptability Theory (Ployhart & Bliese, 2006) and from a skill acquisition perspective (e.g., Ackerman, 1988). The effects of cognitive ability (i.e., perceptual speed and working memory capacity), personality traits (i.e., conscientiousness and openness to experience), and adaptability (i.e., I-ADAPT-M) on adaptive performance were evaluated using a skill acquisition task (i.e., the noun-pair lookup task) with an undergraduate student sample.

Performance on the Noun-Pair Lookup Task

The noun-pair lookup task has been used as a relatively simple skill acquisition task (e.g., Hertzog et al., 1996; Hertzog et al., 2007). In this dissertation study, performance on the noun-pair lookup task mostly replicated previous findings (e.g., Ackerman & Woltz, 1994; Touron & Hertzog, 2004a). That is, performance improvement was much shallower in the VM task than it was in the CM task. The performance trajectory on the CM task also followed the pattern of a typical skill acquisition curve that performance improves with practice and reaches its asymptote after extensive amount of practice.

Unlike previous studies, this dissertation had two conditions in which changes from the CM task to the VM task were introduced at difference performance stages of the CM task. In the early-change condition, the change was introduced at an early stage of CM skill acquisition, whereas in the late-change condition, the change was introduced at a late stage of CM task learning. Across conditions, participants went through the same amount of the CM practice and had similar skill acquisition trajectories and yet their absolute level of performance differed. In the early-change condition, participants on average did not reduce their RTs to less than 1s, but participants in the late-change condition did. This significant difference may be explained by the analysis on the strategies participants used when performing the CM task. Although the difference of the proportion of retrievers in each condition at the end of the CM task was only marginally significant, retrievers in the late-change condition brought down the mean RTs in the late-change condition to less than 1s.

Although the difference in the proportion of retrievers at the end of the CM task between the two conditions did not reach statistical significance, it showed the trend that participants in the late-change condition seemed to be more likely to adopt a retrieval strategy than those in the early-change condition. In the early-change condition, the unforeseen change to the VM task may have led participants to have some expectations of the reoccurrence of the change and therefore they, or at least the scanners, did not think it was necessary to memorize the noun pairs and switch to a retrieval strategy.

There were two findings in this study that were not in line with Ackerman and Woltz (1994). First, in the late-change condition, the between-subjects SDs in the CM task decreased to a level that was smaller than that in the VM task. Ackerman and Woltz found that the between-subjects SDs in the CM task were larger than those in the VM task. One possible reason may be that in Ackerman and Woltz's (1994) study, VM and CM tasks were administered between-subjects, which may have increased the variance in performance. Another possibility could be due to sample differences. It is assumed that there is a range of restriction with the sample in this study whereas the sample in Ackerman and Woltz (1994) recruited from University of Minnesota had larger variances on ability factors. For example, the average SAT score in University of Minnesota is around 1200 whereas the average SAT score of the students from whom participants were recruited for this study is around 1400.

Another finding that was not in line with previous studies was the relationship between working memory capacity and CM task performance over time. Ackerman and Woltz (1994) reported that for the CM task, the relationship between reasoning ability and task performance remained stable over practice, because association learning relied on reasoning ability. However, in this study, the relationship between working memory capacity and task performance was found to decline over time and the pattern was similar for both conditions. This finding could not be directly compared to Ackerman and Woltz's results because different ability constructs were examined in the two studies. However, the declining relationship between working memory capacity and task performance revealed in this dissertation study was more aligned with a skill acquisition framework where general abilities are important early in learning. With practice, performance should rely less on general abilities, especially for such a simple task.

Did The Timing Of The Change Matter?

Hypothesis 1 stated that the relation between ability and adaptive performance would be moderated by the performance stage at which a change was introduced. This hypothesis was not supported. The hierarchical regression did not reveal any significant interaction between ability and working memory capacity and condition. The main effects of condition and perceptual speed were significant, indicating that the performance decrement due to the unexpected change to the VM task was larger when the change was introduced at a later stage of CM learning and the performance decrement was smaller for those with better perceptual speed ability. Although there was no evidence supporting the moderation effect of performance stage at which a change was introduced, the main effect of condition indicated that the performance stage at which a change was introduced did have an effect on the post-change performance in general. When people almost master a skill/task and then encounter a change unexpectedly, they will have larger performance decrements than when they are still in the learning process and experience a change.

Post hoc analyses also revealed an interaction of the performance stage at which a change was introduced and the dependability dimension of conscientiousness for predicting the post-change performance. For people high on dependability, it did not matter whether a change was introduced at an early stage or at a later stage. For people with low dependability, those in the late-change condition had more performance decrements than their counterparts in the early-change condition. Those who were less likely to maintain order and stick to old rules seem to become less adaptive if the change of rules occurs later in their learning and skill acquisition than earlier. This result also supported the suggestion that the effect of conscientiousness should be examined at its facet level (e.g., LePine et al., 2000). Especially in the context of adaptive performance where changes are involved, the dependability and achievement dimensions may exert different effects on performance.

Strategy Use

One characteristic of the noun-pair lookup task is that it enables strategy selection in its CM task. In the CM task, either a retrieval strategy or a scanning strategy can lead to satisfactory performance although a retrieval strategy can substantially improve performance. Given the flexibility of choosing a strategy and of switching from one strategy to the other, what strategy would participants choose and why do they choose one strategy over another?

Strategy was determined by examining RTs in the CM task. Participants were dichotomized into either scanners or retrievers. Ability and personality traits were examined to explore their effects on strategy use (Schunn & Reder, 2001). Based on the results of multiple linear regression analysis, in the early-change condition, perceptual speed and working memory capacity were the two most significant predictors of performance on CMpart2 and CMpart3 (see Table 4, p.56). That is, people with higher working memory capacity and people with faster perceptual speed had shorter RTs on CMpart2 and CMpart3 practice. Therefore, they were more likely to be using a retrieval strategy because only a retrieval strategy could enable substantial RT reduction. It is likely that participants with high working memory capacity could memorize the noun-pairs faster and more easily than those with lower working memory capacity. As such, retrieval from memory was not very effortful for them.

In the late-change condition, for CMpart2, perceptual speed was a significant predictor of performance and the predictive power of openness to experience was close to significance. For CMpart3, openness to experience became a significant predictor of performance and perceptual speed had a marginally significant relationship with performance. In other words, participants with faster perceptual speed and participants with high openness had shorter RTs on CMpart2 and CMpart3 and they were more likely to be using a retrieval strategy. The positive predictive power of openness to experience on strategy choice partly supported Hypothesis 2. People with high openness to experience are thought to be likely to try new things. In the context of noun-pair lookup CM task, participants who were high on openness to experience were more likely to try to memorize the noun-pairs and realize the substantial performance improvement with the retrieval strategy. As such, they were more likely to become retrievers.

The individual differences factors that were found to be related to strategy use were not consistent across conditions, especially openness to experience. Openness to experience was not a significant predictor in CMpart2 and CMpart3 in the early-change condition, but it was predictive of strategy use in the late-change condition. As mentioned earlier, the change to the VM task was introduced after a relative brief period practice on the CM task in the early-change condition, which may have led participants to expect more changes. As such, they may not have been willing to try new strategies and/or they were not fully committed to new strategies. Therefore, the only individual differences factors that played a role in strategy use were the ability factors. In contrast, in the late-change condition, the change to the VM task was not introduced until after extensive practice on CM task. Practice, in addition to a participant’s ability to memorize the word pairs, his or her openness and willingness to try new things, could play a role in the strategy they chose.

The inconsistent findings in the two conditions regarding the effect of openness to experience on strategy choice deserve future research attention. The findings in this study at least suggest the necessity of taking into consideration the importance of the stage of skill acquisition at which changes are introduced in future studies of adaptive performance. As discussed above, a change introduced early in learning and a change introduced later in learning can affect subsequent performance differently.

Another issue worthy of note is that although the classification of scanners and retrievers based on RTs was confirmed by the performance comparisons between the two, it is possible that some scanners used a combination of scanning and retrieval strategies. Rogers and Gilbert (1997) used a more sophisticated method to classify strategy use. They derived the criterion for categorization based on the estimation of participants' fastest VM scanning rate of 1080 VM task trials. Their method was not appropriate for this study, given that participants only practiced 180 VM task trials in this study and the estimation based on this number of trials is not likely to be reliable.

The Mediating Effect of Adaptability

Adaptability was proposed by Ployhart and Bliese (2006) as a composite of ability, personality, knowledge and other personal characteristics. In the I-ADAPT Theory, adaptability functions as a mediator between the more distal predictors (e.g., ability, personality traits) and adaptive performance. Ployhart and Bliese (2006) also developed the I-ADAPT-M to measure adaptability from sub-dimensions and suggested that the overall adaptability is a weighted composite of the eight sub-dimensions. However, Ployhart and Bliese (2006) did not provide a well-developed framework on how to determine the weights for each sub-dimension in different contexts.

In this study, overall adaptability was computed as an unweighted composite of the eight sub-dimensions, given that the criterion task was relatively simple. Following the standard procedure of examining mediating effect (Baron & Kenny, 1986), no significant results were found. Adaptability was correlated with openness to experience, achievement dimension of conscientiousness, and marginally correlated with working memory capacity (measured by operation span). More studies examining the relationship between adaptability and personality are warranted to determine whether adaptability is an independent construct from personality, or just manifested personality in different contexts.

The adaptability trait proposed by Ployhart and Bliese (2006) is a multi-facet construct and its effect may not be manifested in a relatively simple skill acquisition task. The I-ADAPT-M may be more suitable to capture adaptive performance in its full criterion scope (i.e. adaptive task performance and adaptive contextual performance), rather than just adaptive task performance on a relatively simple task.

Limitations and Future Directions

It was clear that participants' performance trajectories, specifically their performance at the end of the CM task, were statistically different between the early-change and the late-change conditions. However, it was hard to attribute this difference to a single between-subjects factor. Given that this study did not use a fully-crossed design, the two conditions differed not only in when a change was introduced (i.e., early-change vs. late-change) but also in the task that they started with (i.e., the early-change condition started with the VM task and the late-change condition started with the CM task) as well as the total number of changes (i.e., shifts between the CM task and the VM task) introduce throughout the noun-pair lookup task. In other words, it is impossible to tease apart the effects of these between-subjects variables: the performance stage at which a change was introduced, the prior practice on the VM task and the number of changes introduced. Future studies can separate the effect of performance stage at which a change is introduced.

As to the measures of perceptual speed, Finding A's test and Identical Pictures were not highly correlated and performance on the Identical Pictures test was not consistently predictive of performance on the noun-pair lookup task between the two conditions, whereas performance on the Finding A's test did. As such, only performance on Finding A's test was used as the measure of perceptual speed instead of creating a composite out of the two measures. This study showed that performance on Identical Pictures test was not a good predictor of performance on the noun-pair lookup task. Future studies should be more careful in choosing predictor measures and the post-hoc selection is better to be avoided. As aforementioned, the I-ADAPT-M also requires future studies to examine its validity in predicting adaptive performance.

Although no moderation effect of performance level at which a change was introduced on the relationship between ability factors and post-change performance was found, this study did show a moderation effect of the timing of the change on the relationship between dependability and post-change performance. Future studies exploring the relationships between individual differences factors and post-change performance should also take into consideration the issues of when a change is introduced and what performance level is before a change is introduced. Future studies can also extend to tasks that have different levels of complexity and consistency and explore how task complexity and consistency play a role in affecting adaptive performance. With regard to the I-ADAPT theory, to fully examine the proximal – distal framework, more complex tasks should be used that enables the eight, or most of the eight, sub-adaptabilities play a role in adaptive performance.

CHAPTER 6

CONCLUSION

This dissertation revealed that participants in the two conditions performed differently in skill acquisition, although further studies are needed to explore the exact cause of this difference: the timing of the change or the amount of the change. Additionally, this study suggests that when a change is introduced also has impacts on how people select strategies in post-change periods and on how ability and personality factors affect post-change performance. This dissertation did not support the moderation effect of performance stage at which a change is introduced on the relationship between ability factors and adaptive performance, nor the mediating effect of adaptability on the relationship between proximal predictors (e.g., ability and personality factors) and adaptive performance.

Overall, this dissertation study contributed to current adaptability and adaptive performance research in several ways. First, it called for a clear distinction between adaptability and adaptive performance and it is among the first to test critical portions, including the relationship between adaptability and adaptive performance, of the model specified by the I-ADAPT Theory. It suggests the necessity of further developing and validating the I-ADAPT Measure with more complex tasks. Second, this dissertation provides evidence for the importance of examining personality traits when investigating strategy use on cognitively demanding tasks in the context of adaptive performance. Most importantly, this dissertation study was a first attempt to explore the relationship between individual differences factors and adaptive performance by taking into consideration skill acquisition stages when introducing changes. By showing when a change was introduced during skill acquisition processes did matter, this dissertation calls for attentions of those who conduct research on adaptive performance to seriously consider when to introduce a change rather than just introduce a change in the middle, or after other arbitrarily decided performance stages. This dissertation should also spur interest in further exploring the relationship between individual differences factors and adaptive performance under the framework of skill acquisition, using more complex tasks with well understood characteristics.

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Appendix Noun-pair sets used for the VM and the CM tasks

VM task set 1:

Milk	Door	Texas	Apple	Rabbi	Yale	Beer	Golf	Zinc
Rose	Shoe	Hour	Nurse	Theft	Salt	Knife	Steel	Maple

VM task set 2:

Robin	Waltz	Italy	House	Tent	Paris	Cobra	Corn	Polio
Mile	Yacht	Head	Wool	Blue	Dime	Rain	Aunt	Doll

CM task set:

Rock	Garlic	Violin	Desk	Tuna	Bike	Week	Boots	Linda
Onions	Table	Canyon	Jeep	Heels	Anne	Harp	Whale	Score